Kansas Citys, Missouri and Kansas Flood Damage Reduction Feasibility Study (Section 216 – Review of Completed Civil Works Projects) Engineering Appendix to the Interim Feasibility Report

# Chapter A-7

# GEOTECHNICAL ANALYSIS FAIRFAX-JERSEY CREEK (BPU FLOODWALL)

# CHAPTER A-7 GEOTECHNICAL ANALYSIS FAIRFAX-JERSEY CREEK (BPU FLOODWALL)

#### A-7.1 INTRODUCTION

This chapter presents the results of the geotechnical evaluation of an area in the Fairfax-Jersey Creek protection unit determined to have a certain probability of failure under the existing level of protection that warranted further study. The determination relies on historical borings and soil test information combined with recent subsurface borings and soil test information.

#### A-7.2 SOURCES OF EXISTING LEVEE DESIGN INFORMATION

The primary sources of information for this geotechnical analysis include the references listed in the References section of this chapter.

#### A-7.3 DESCRIPTION OF THE LEVEE UNIT

Refer to Section A-4.3.7 for a detailed description of the Fairfax-Jersey Creek Unit

#### A-7.4 LEVEE DESIGN FEATURES

## A-7.4.1 Existing Levee and Floodwall Sections

The Fairfax-Jersey Creek levee unit consists of levees, floodwalls, stoplop and sandbag gaps, riprap and levee toe protection, surfaced levee crown and ramps, drainage systems, the Jersey Creek sewer structure and shutter gates, and pumping plants. It was originally constructed as a local levee, but was removed and replaced using Federal standards in 1940. The final contract for construction of the project was completed in 1955.

A plan view of the Fairfax-Jersey Creek Unit and typical sections are provided in the Supplemental Exhibits section as Exhibits A-7.1 through A-7.11.

#### A-7.4.2 Future Flood Protection Concerns

This levee unit is being considered for a partial reestablishment of existing design level of protection near the Kansas River, or the beginning of the project. Some areas have been surveyed and appear to be lower than the original federal design elevation. The remainder of the system is not recommended for a raise based on the hydraulic analysis of the Missouri and Kansas Rivers.

As a result of an evaluation of the existing floodwall near the BPU facilities, it was concluded that Stations 287+85 to 302+32 required further evaluation. The 1993 flood did not reach the top of the floodwall. A full head to the top of the floodwall is analyzed in this chapter.

#### A-7.4.3 Area Site Characterization

The Corps of Engineers' boring and additional subsurface information shown in the Supplemental Exhibits section (Exhibits A-7.12 and A-7.13) was used to characterize and model the foundation resistance for the existing precast concrete piles driven below the existing floodwall. The boring assignment for investigations of the Fairfax area was developed well in advance of the floodwall concerns. One Corps boring was proposed earlier, but was designated for investigation of an existing stoplog gap. The boring was eliminated when it was discovered that the stoplog gap had been permanently sealed. No additional borings were assigned for the study of the floodwall during the earlier stage of general investigations. Later, when concerns were raised regarding the integrity of the floodwall pile length and strength, additional investigations were conducted through a contractor. The Investigation Report is included as Exhibit A-7.14.

These borings were used for developing the resistance to vertical and horizontal loading. The characterization of the floodwall foundation relied on the Standard penetration resistance obtained by driving a split spoon through the foundation sands. An automatic trip hammer was used and appropriate corrections were made for energy input, overburden pressures, rod type, rod length, hole size, and other pertinent variables during the test. This information was used to develop the expected soil strength of the foundation sands (refer to Exhibits A-7.17 through A-7.20).

# A-7.4.4 Pile Capacity

The soil strength and existing pile length and configuration below the pile cap was used to develop a spreadsheet model for determination of the available amount of side friction and end bearing for a circular driven precast concrete pile. The lateral coefficient of friction was chosen for the driven condition and a correction to the resistance was made, taking into consideration the expected foundation underseepage pressure during a high river condition. A flow net was used to model the underseepage pressures. This information was provided to the structural engineering team members for their use. Exhibit A-7.15 and Exhibits A-7.21 through A-7.23 contain the geotechnical calculations for pile capacity. A summary of the ultimate foundation resistance is provided in Exhibit A-7.24.

#### A-7.4.5 Underseepage Analyses

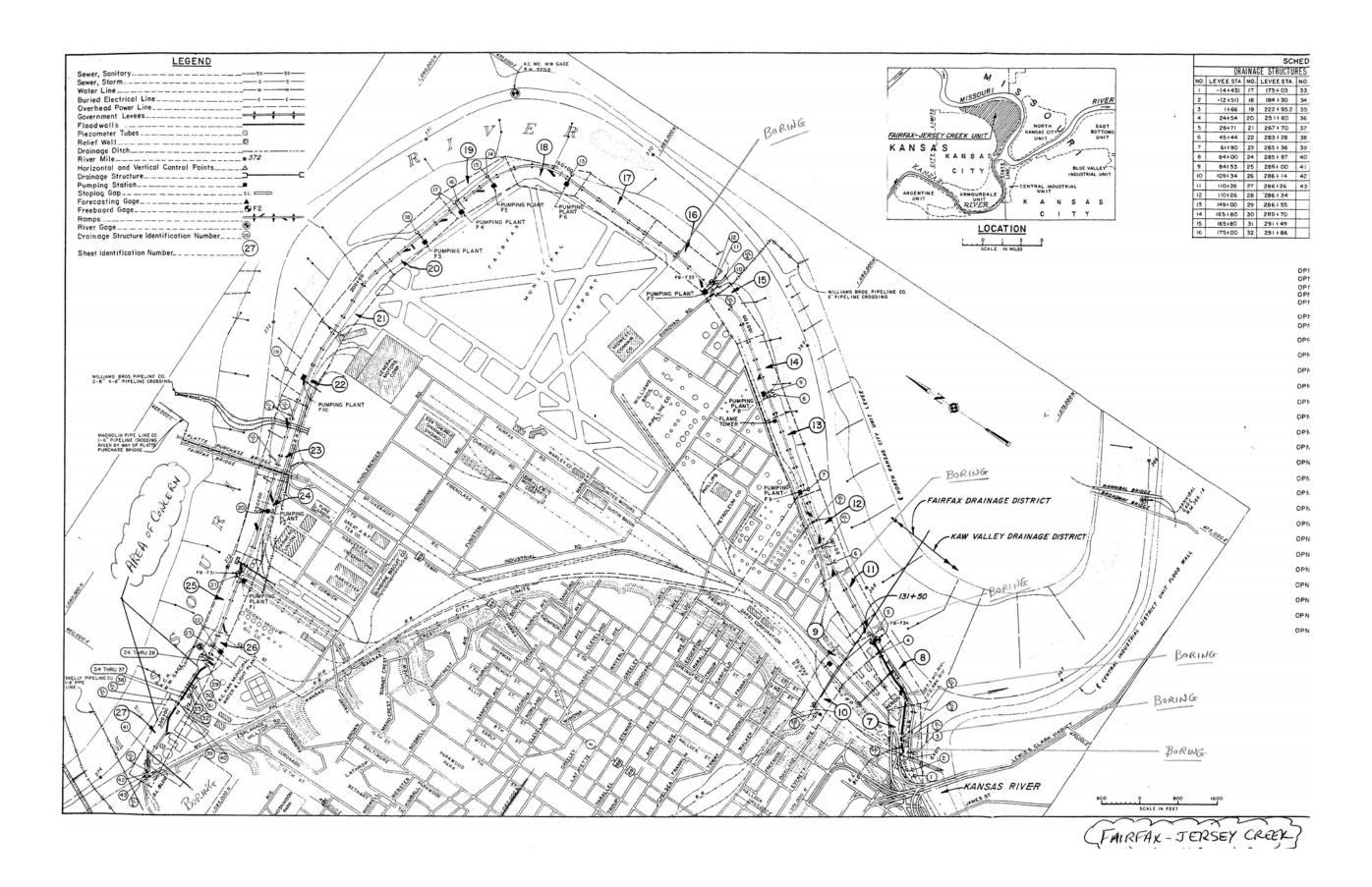
The model used to develop the expected pressure in the foundation sands along the length of the driven piles was a simple hand-drawn flow net. The cutoff wall was ignored and equipotential lines with perpendicular flow lines were developed below a mostly sand foundation. The equipotential lines were used to determine the pressure along the three piles located landside, the middle piles, and the piles riverside of the stem of the floodwall. These tabulated values were added to the model for the resistance to correct for lower effective overburden pressure.

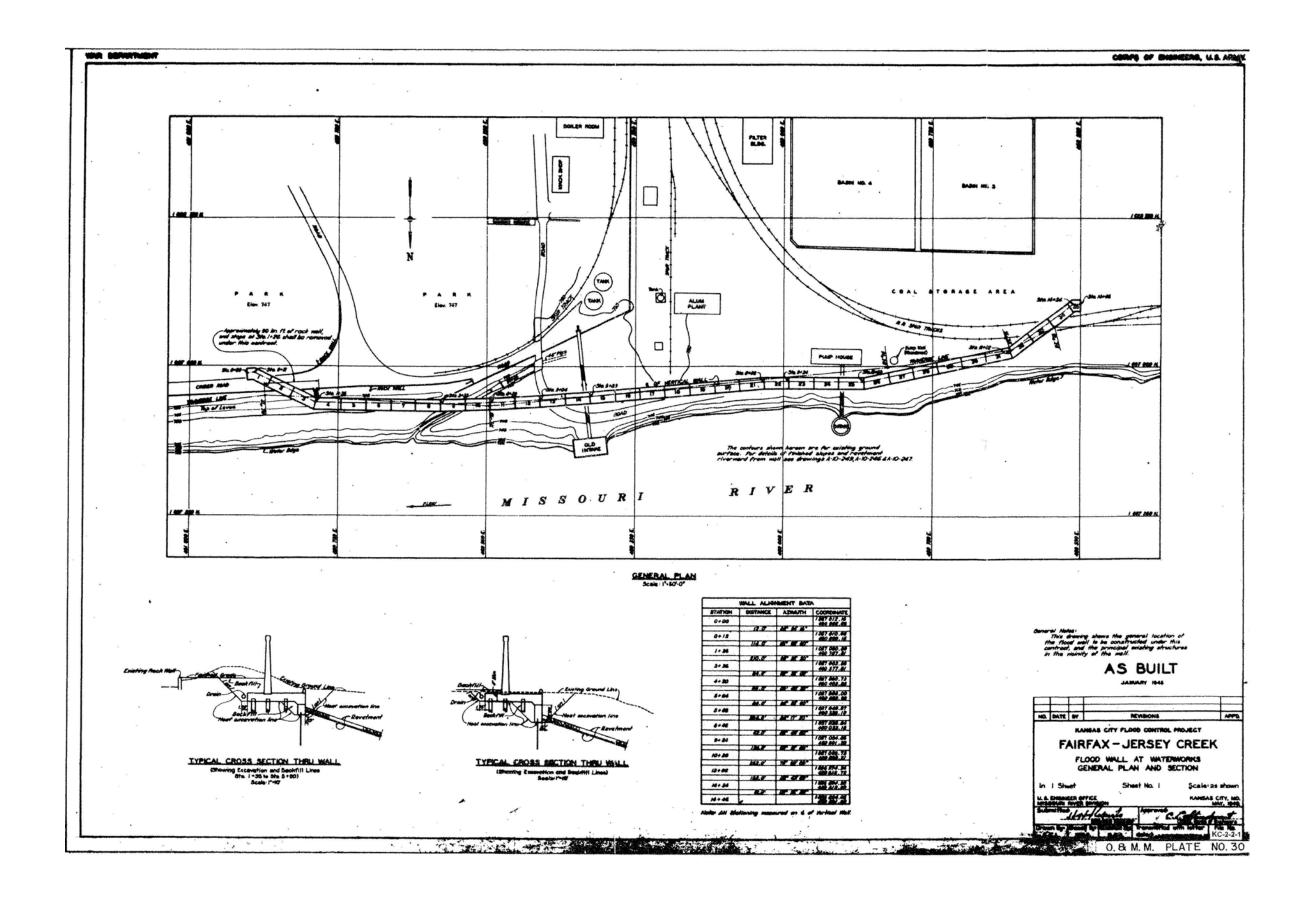
#### A-7.5 REFERENCES

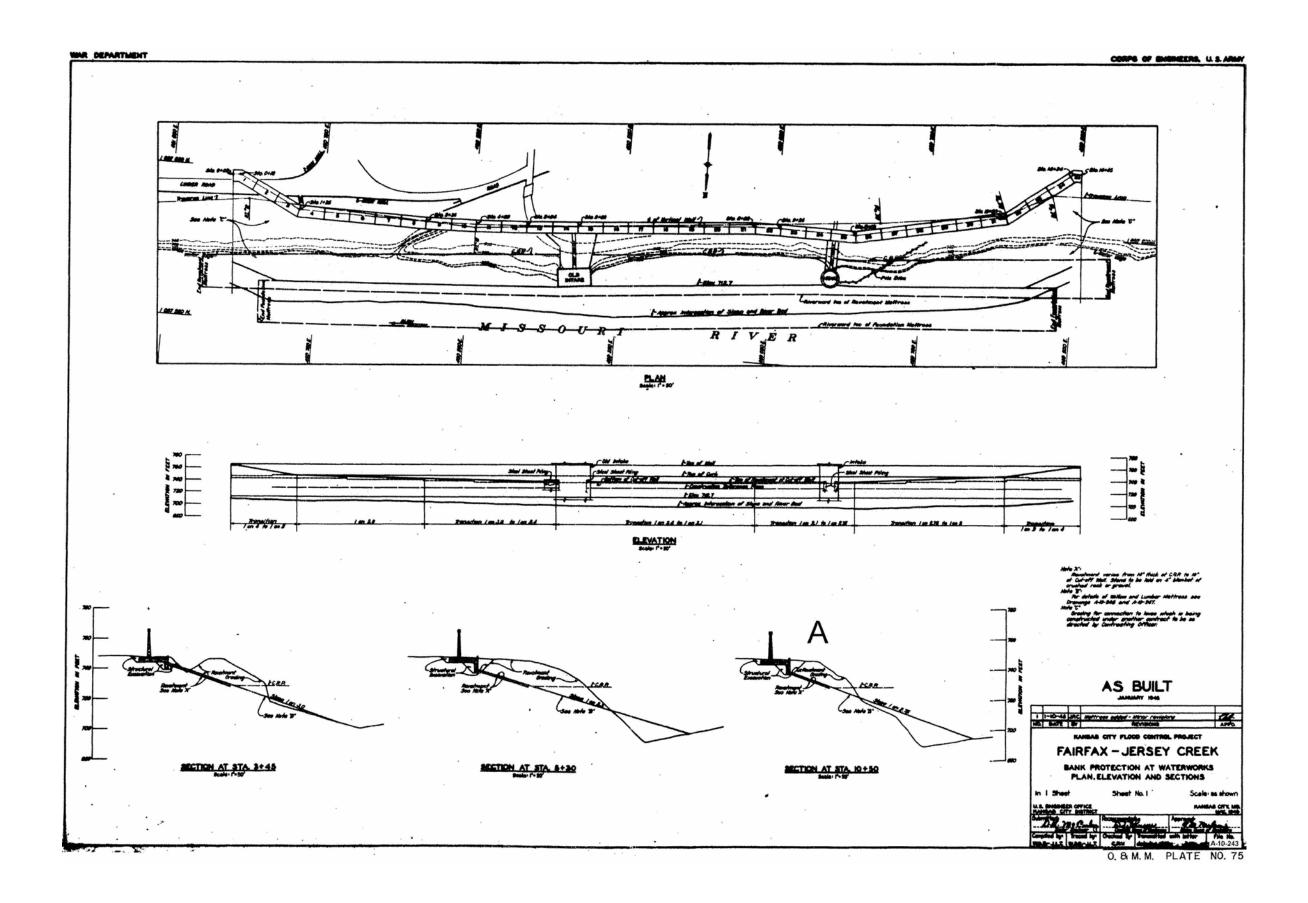
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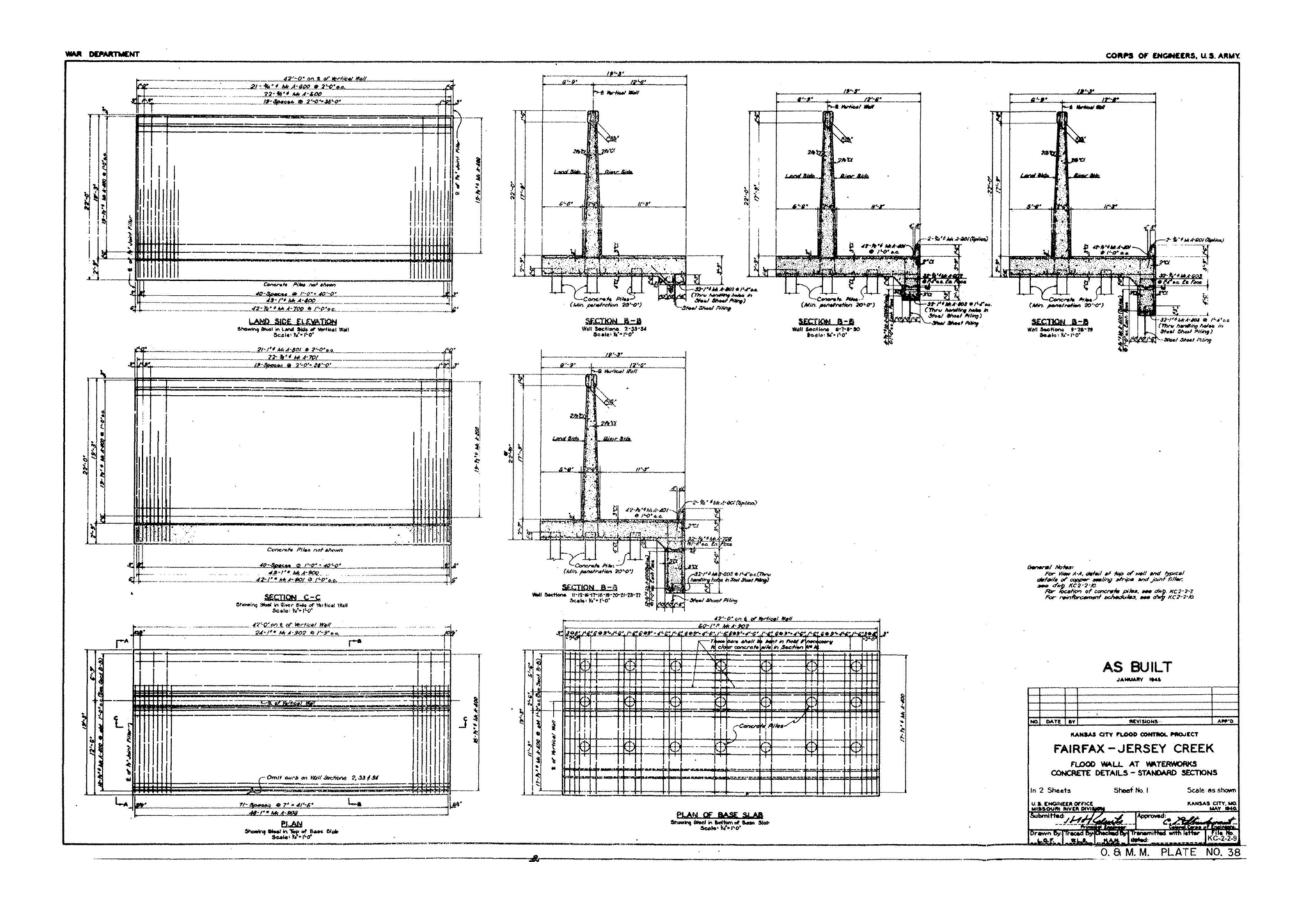
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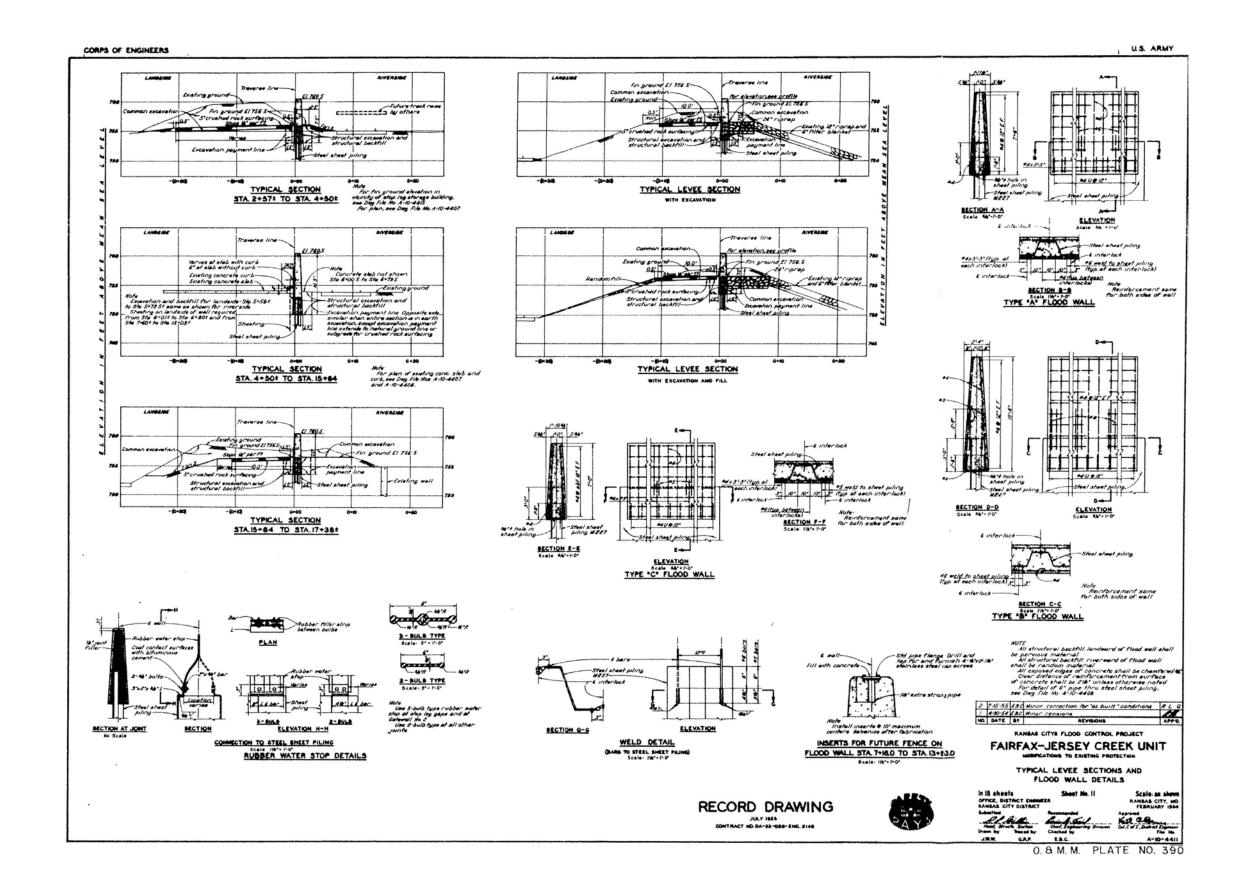
# A-7.6 SUPPLEMENTAL EXHIBITS

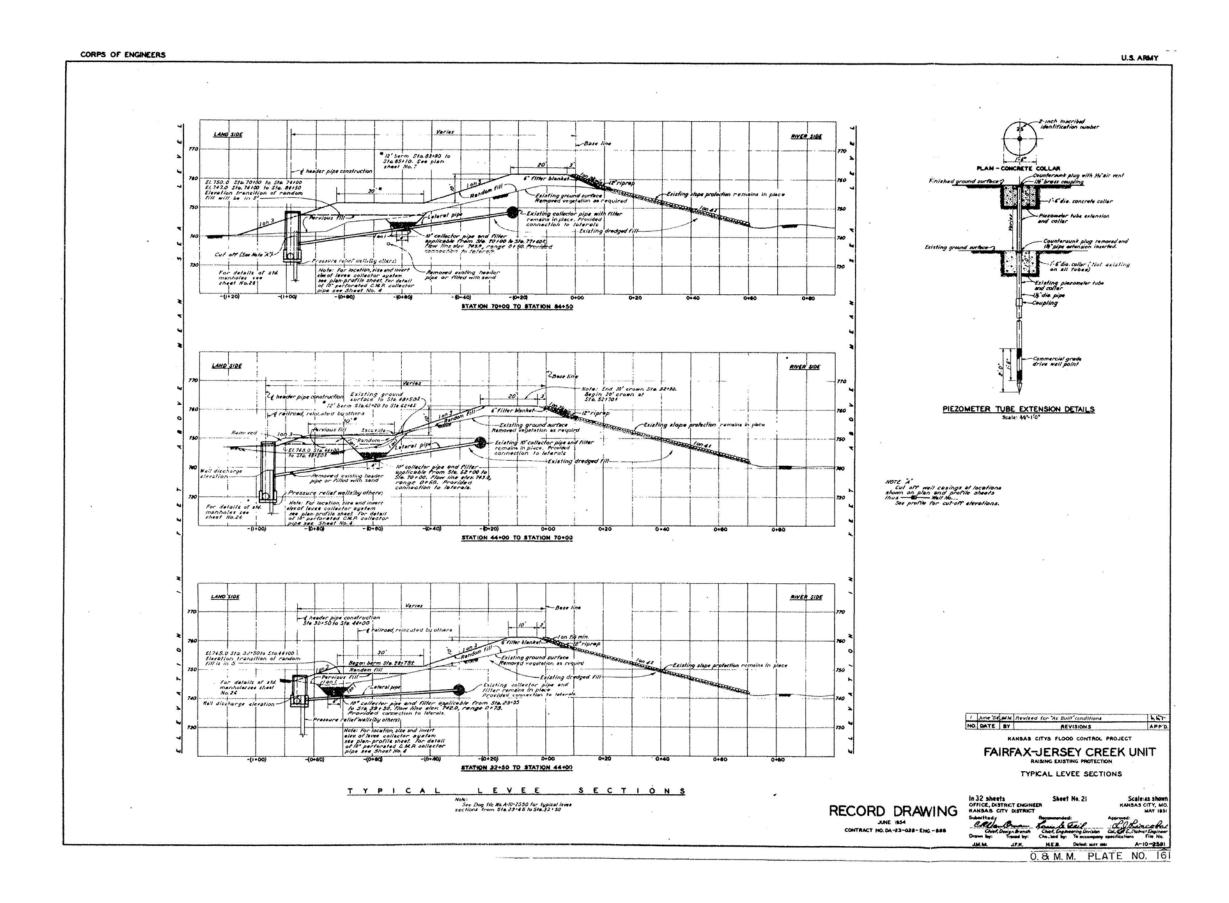


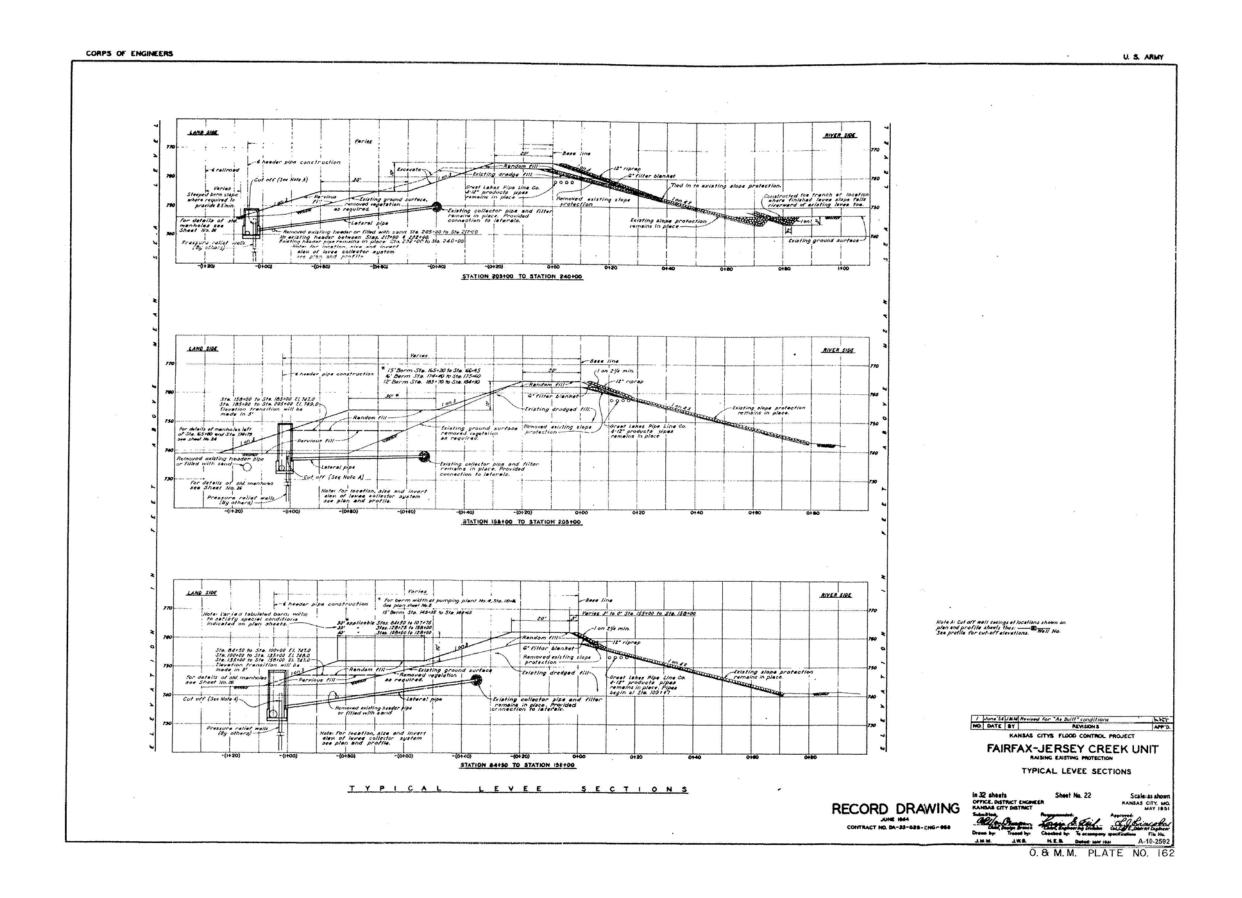


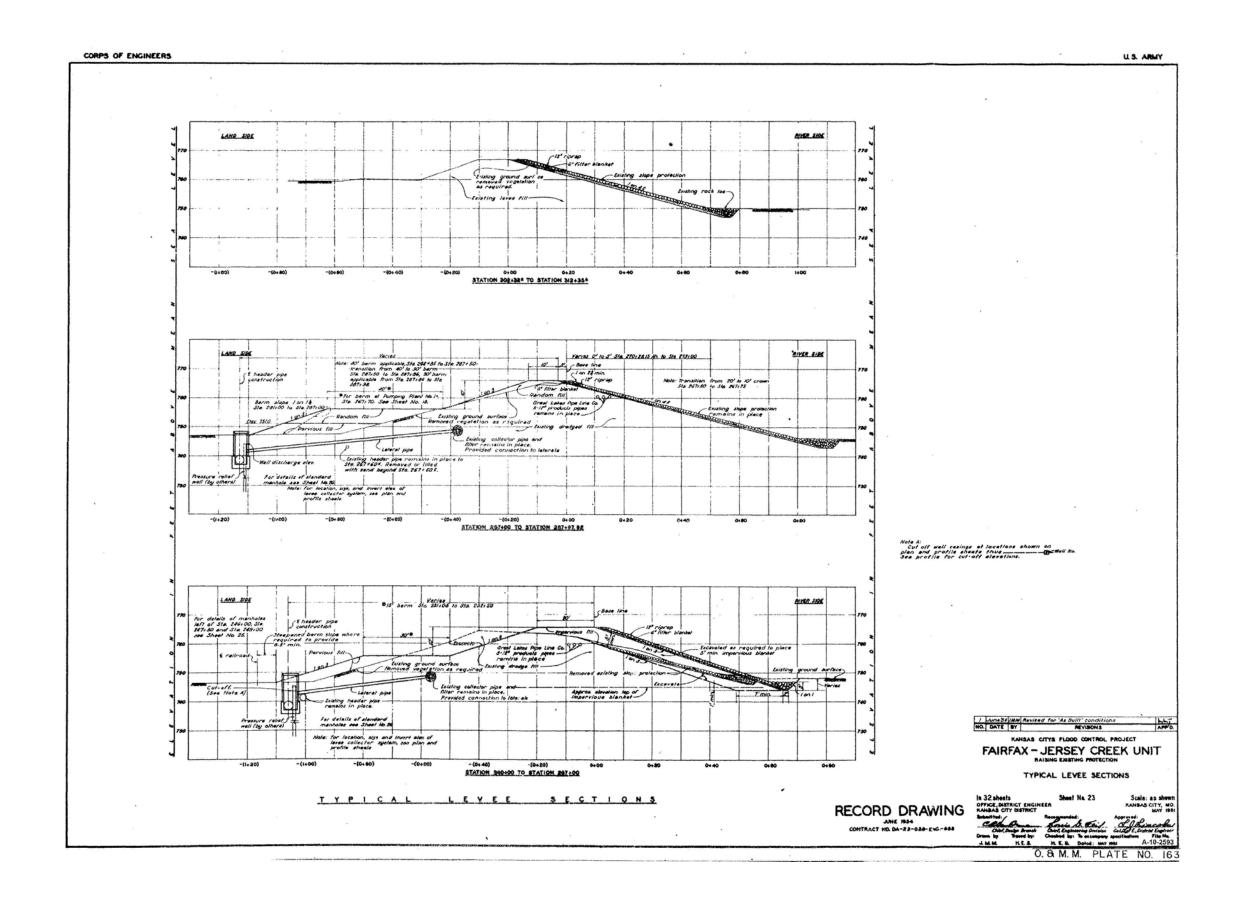


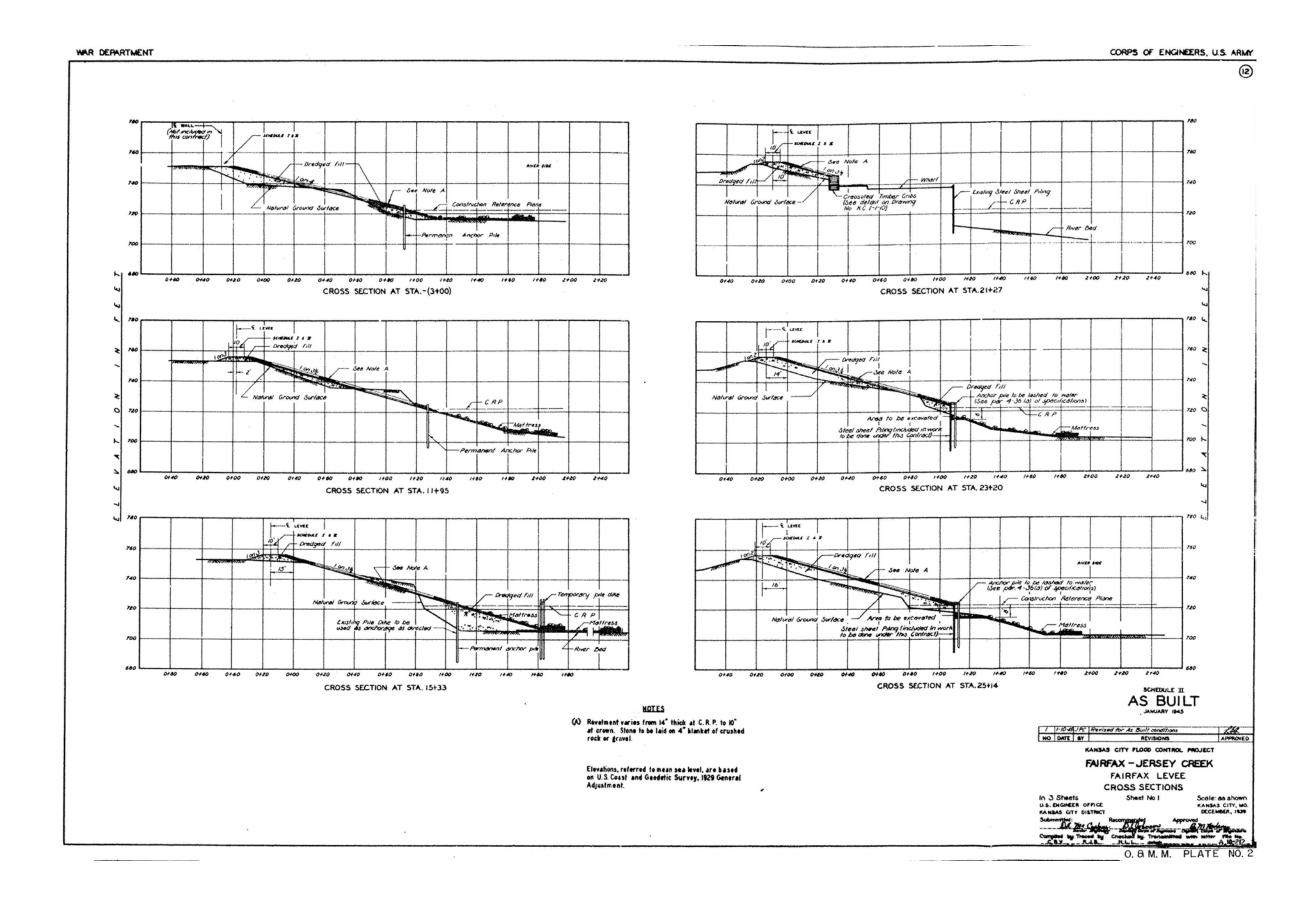


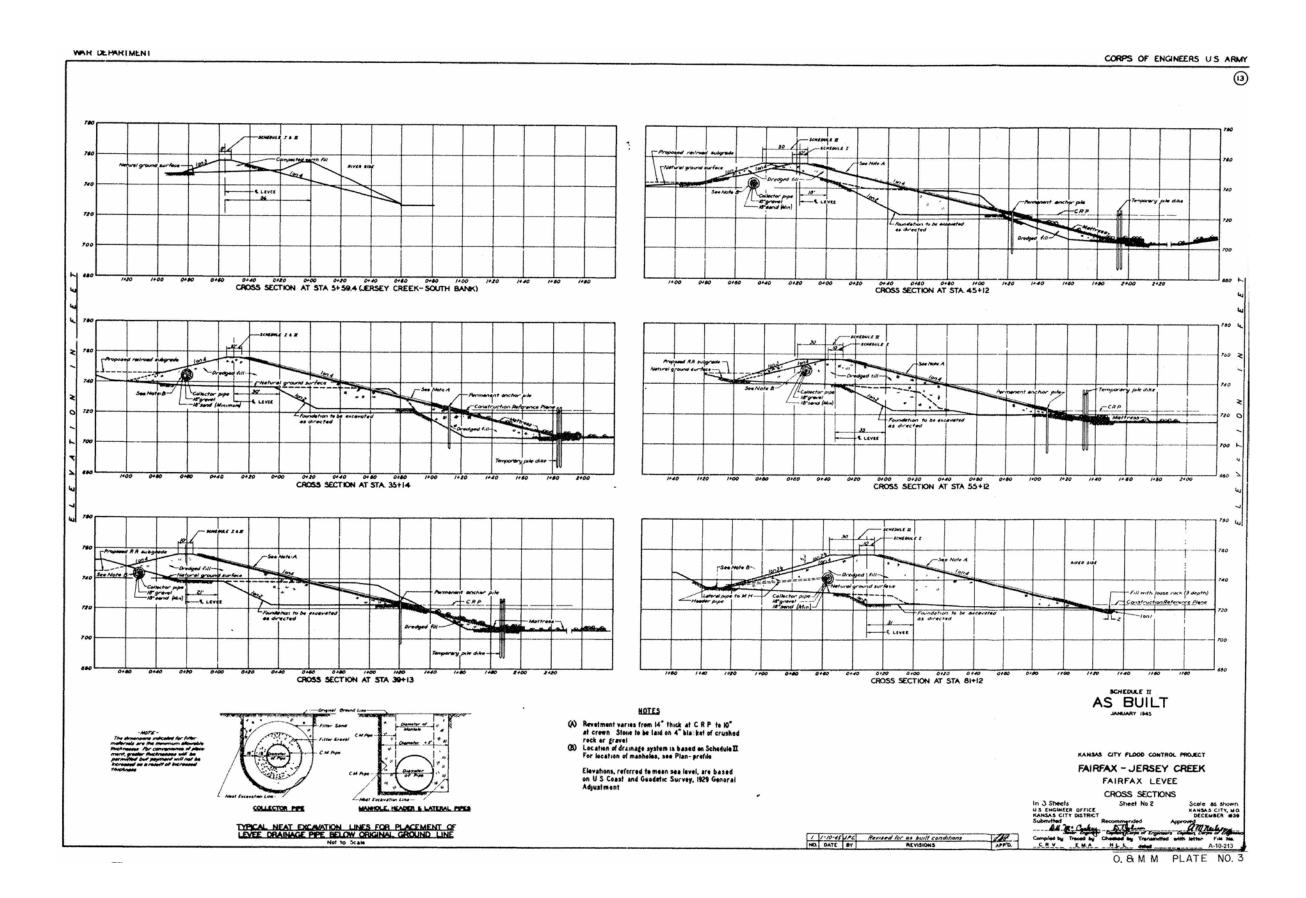


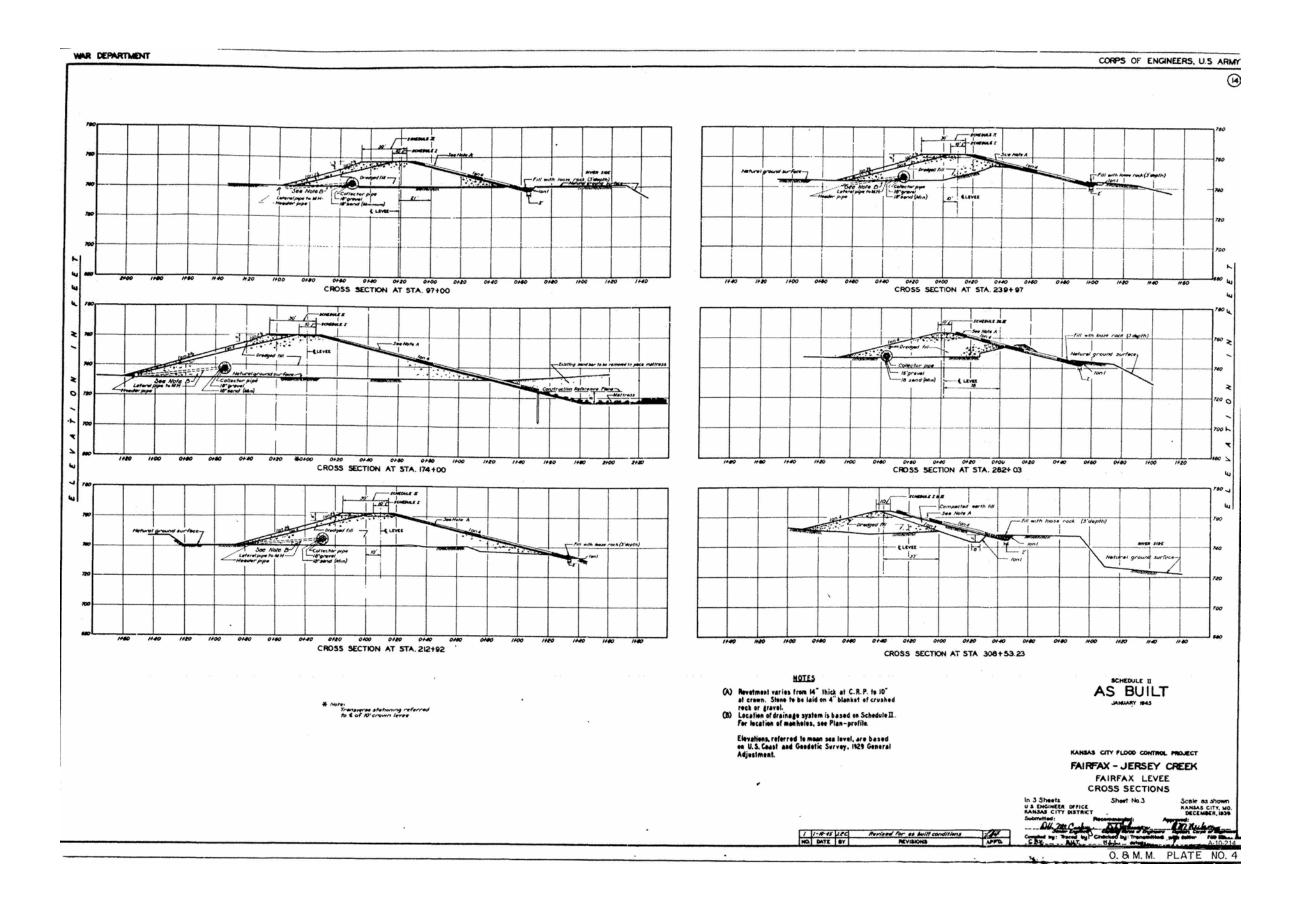




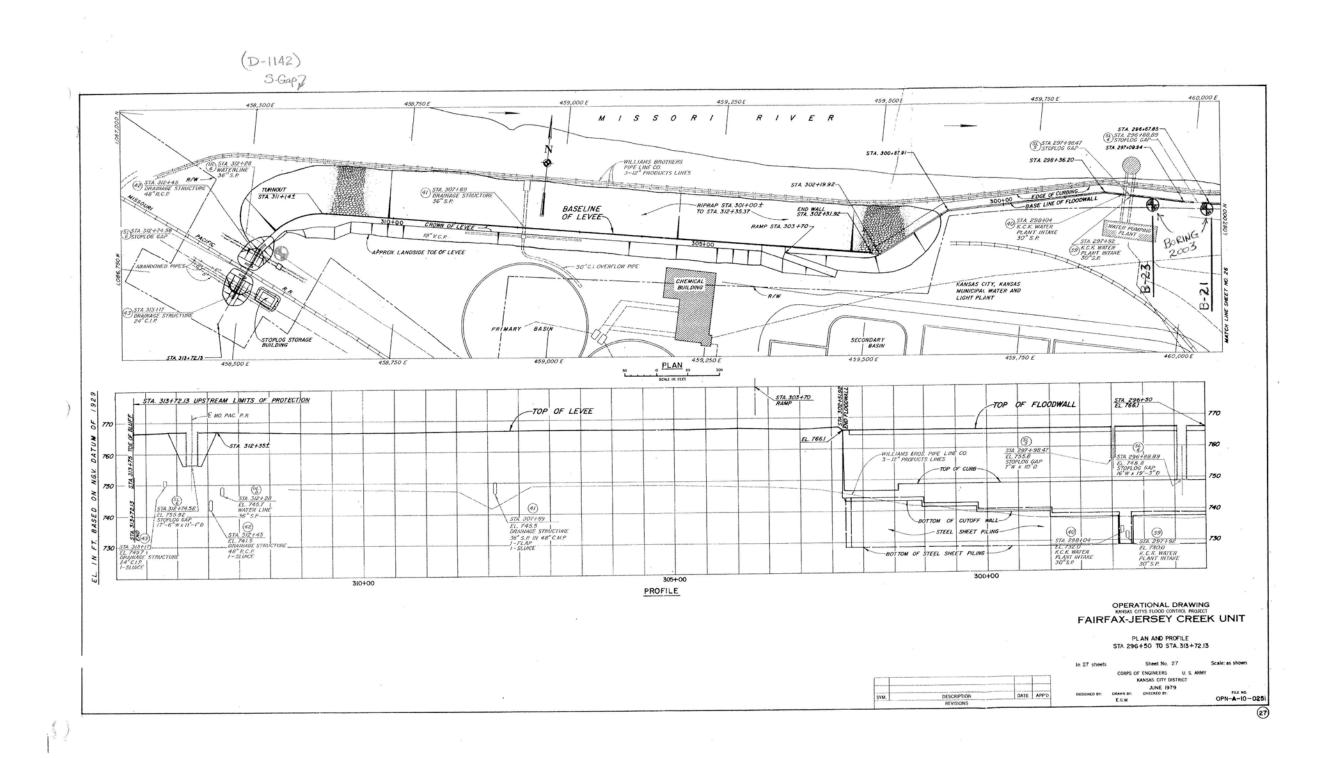








# Site Characterization Maps and Boring Information



461,500 E 461,250 E 461.000E 460,750 E 460,250 E 5 STA. 294 + 20.5 END 3-16" CASINGS NTAKE 24 25 26 27 28 STA 291 + 49 DRAINAGE STRUCTURE 4'X 6' RCB STA. 289 + 70 DRAINAGE STRUCTURE 24 C.I.P. INTAKE 2003 STA 285+87 TO STA 286+34 QUINDARO POWER PLANT NO 3 1-8"SP, 1-54" SP, 3-108" SP BORING STA. 292+90.06 STA. 291+21.55 STA. 293+ 13.97-OUTFALL STA. 289+11.76 295+00 EDGE OF CURBING 290+00 \_LINE B 108" (34) (35) (36) (37) STA.283+28 DRAINAGE STRUCTURE 30"SP LINE C 108" STA 286+84 STA 293+60 TO STA 293+89/ QUINDARO POWER PLANTS NO. 1 AND 2 3-48" C.I.P. 1-24" C.I.P. -WILLIAMS PIPE LINE CO 3-12" PRODUCTS LINES 42" C.I.P. STA 295 + 59 DRAINAGE STRUCTURE 6"C.I.P. ABANDONED 42" C.I.P. CROWN OF LEVEE BARRICADE LEND\_DE\_ACCESS) STA 291 + 86

DRAINAGE STRUCTURE
4'X 6'R.C.B. COLLECTOR PIPE STA. 292 + 69
DRAINAGE STRUCTURE
30" C.I.P. 00 STA. 206+56 12-4" ELEC. FIBER DUCTS 1-4" X 3' R.C.B. HEADER PIPE KANSAS CITY, KANS. MUNICIPAL WATER & LIGHT PLANT WELL-140 LANDSIDE TOE PLUGGED LATERAL WITH CONCRETE RIVERWARD END--DRAINAGE PUMPING PLANT 461,500 E PLAN 461,000 E 461,250E 460,750 E 1.086.750 N STA 286+64 SERVICE BRIDGE INTAKE TOWER -TOP C TOP OF FLOODWALL STA. 296+50 EL. 766.1 27) STA 286+26
EEL 759.2
WATERLINE QUINDARO
POWER PLANT NO 3
8" SP 22)<sub>STA</sub> 283+28 EL. 765.3 DRAINAGE STRUCTURE 30" SP 30 STA. 289 + 70

EL. 733.8

DRAINAGE STRUCTURE
24 °C.I.P.
I - GATE VALVE EL. 765.8 WILLIAMS BROS. PIPE LINE CO. STA 295 + 59
EL 73.0.5
DRAINAGE STRUCTURE/
6" CI.P.
1- FLAP
1- GATE VALVE 33 DRAINAGE STRUCTURE
30°C.I.P
1-FLAP
1-GATE VALVE STA 286+55 CL-EL. 758.0 12-4" ELEC. FIBERDUCTS 1'-4" X 3' R.C.B. GROUND SURFACE AT GROUND SUR!

TOE OF BERM

STA 285+25

WELL-140

STA 285+87

24 EL.750.1

24 OUINDARD POWER PLANT NO.3
54 SP (INE 0)

I-BUTTERFLY VALVE HEADER STA. 286+34
EL. 739.9
QUINDARO POWER
PLANT NO. 3
108" SP
BUTTERFLY VALVE STEEL S
PILING

STALP93 do

STALP93 do

STALP93 do

OUNDARO POWER PLANT

STALP94 + 86

EL 736.4

STALP94 + 70

OUNDARO POWER PLANT

STALP94 + 86

EL 726.4

OUNDARO POWER PLANT

OUNDARO POWER PLANT

NO. I AND 2

4" C.I.R

I - FLAP

1- FLAP

48" C.I.R STEEL SHEET-(23) STA. 283 + 36 EL. 731.3 DRAINAGE STRUCTURE 42°C.I.P I-SLUICE AL | 26 | 286 + 14 | 261 / 2731.4 | 261 / 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 | 2731.4 STA 293 + 89 EL 730 2 OUINDARO POWER PLANT NO. 1 AND 2 48" C.I.P. STA.293+8-STA.291+49 EL.730.6 DRAINAGE STRUCTURE 4'X6' R.C.B. I-FLAP 25 STA 286 + 00

EL 73.4

OUINDARDO POWER PLANT NO.3

108" SP (LINE C)
1- BUTTERFLY 2 36) EL. 729.6 QUINDARO POWER PLANT NO. 1 AND 2 24" C.I. P 290 +00 295+00 PROFILE FAIRFAX - JERSEY CREEK - KANSAS

# EXHIBIT A-7.14 Flood Wall Pile Investigation Report

# Fairfax Drainage District Flood Wall Pile Investigation Report October 20, 2003

U.S. Army Corps of Engineers, Kansas City District

Contract No. DACW 41-02-D-0006

By

Black & Veatch Special Projects

Overland Park, Kansas

October 20 2003

Page 2

Corps of Engineers, Kansas City District Mr. Lamar, McKissaci

B&V Project 41177 October 20, 2003

Attachment A Fairlax Flood Wall Pile Investigation Report

SUBSURFACE EXPLORATION AND GEOPHYSICAL SURVEYS FAIRFAX FLOOD CONTROL SRUCTURE KANSAS CITY, KANSAS

Prepared for:

U.S. ARMY CORPS OF ENGINEERS, KANSAS CITY DISTRICT C/O BLACK & VEATCH

Overland Park, Kansas

Prepared by:

GEOTECHNOLOGY, INC. Overland Park, Kansas

Geotechnology Job No. 0713201.3211

October 15, 2003

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# SUBSURFACE EXPLORATION AND GEOPHYSICAL SURVEYS FAIRFAX FLOOD CONTROL SRUCTURE KANSAS CITY, KANSAS

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# SUBSURFACE EXPLORATION AND GEOPHYSICAL SURVEYS FAIRFAX FLOOD CONTROL SRUCTURE KANSAS CITY, KANSAS

#### **SECTION I - EXECUTIVE SUMMARY**

The executive summary is provided solely for the purposes of overview. The executive summary omits a number of details, any one of which could be crucial to the proper application of this report. Any party who relies on this report must read the full report.

- The project includes conducting an investigation to determine the length of existing piles and the subsurface soil conditions at the Fairfax flood control wall at Monoliths 16, 21 and 23.
- Below the surficial topsoil and silty clay fill, the soil stratigraphy general consists of silty sand underlain by fine to coarse sand.
- After subsurface exploration, the borings were enlarged to install 4-inch diameter PVC pipes for geophysical surveys. Three geophysical methods including parallel scismic, ground penetrating radar (GPR) and magnetic gradient were utilized: The distance from top of pile caps to the bottom of piles were between 21 to 25 feet and the reinforcing steel is between 10 to 13 feet below the top of the pile caps.
- The bottom of the pile cap and the upper 12 to 24 inches of a pile at Monolith 21 were exposed at the face of the excavation to determine the pile shape and cross-sectional dimensions. The exposed pile shows the existing piles are approximately 14-inch diameter, cast-in-place concrete piles (based on a measured pile circumference of 48 inches).

## **SECTION II - PROJECT DATA**

### **AUTHORIZATION**

The services documented in this report were provided in accordance with the terms, conditions and scope of services described in Geotechnology's August 7, 2003 proposal.

### PURPOSE AND SCOPE OF SERVICES

The purpose of our services was to conduct subsurface exploration and geophysical surveys for the investigation of the existing piles as defined in our proposal. Briefly, services consisted of site reconnaissance, drilling three borings, laboratory testing, geophysical surveys and data interpretation, and preparation of this report. Important information prepared by The

U.S. Army Corps of Engineer, Kansas City District C/O Black & Veatch October 15, 2003 Page 2

0713201.3211

Association of Engineering Firms Practicing in the Geosciences (ASFE) for studies of the type is included in Appendix A for your review.

#### PROJECT AND SITE DESCRIPTION

This project included an assessment of the soil conditions adjacent to the existing piling and a determination of the pile length for the Fairfax Drainage District Floodwall in Kansas City, Kansas. The shape and cross sectional dimensions of the existing piles were examined by exposing the pile cap and the upper 12 to 24 inches of pile at Monolith 21, and by exposing the pile caps only at Monoliths 16 and 23. The pile lengths were determined using a total of three types of Borehole Geophysical Surveys (parallel seismic, ground penetrating radar, and magnetic gradient) at Monoliths 16, 21 and 23. This investigation consisted of exposing the pile caps to permit a hammer strike at the top of the concrete to generate a signal source for performing the parallel seismic surveys and performing subsurface explorations. The subsurface explorations included drilling three 50-foot deep bore holes, installing 4-inch diameter PVC pipes, and associated down-hole geophysical surveys. The bore holes were located in the BPU power plant and were drilled adjacent to the existing pile caps.

#### SECTION III - FIELD EXPLORATION AND LABORATORY TESTING

#### FIELD EXPLORATION

The field subsurface exploration consisted of drilling and sampling three borings, designated as Borings B-16, B-21 and B-23, at the approximate locations at Monoliths 16, 21 and 23. All soil borings were drilled and sampled at the above referenced project site from September 22 through 25, 2003,. The borings were located in the field by the client.

All borings were drilled to a depth of 50 feet and were drilled using a CME 55 rotary drill rig. The boreholes were drilled using 4-inch flight augers to a depth of 15 feet with rotary wash drilling methods used from a depth of 15 feet to the boring termination depth of 50 feet below ground surface. Standard Penetration Tests (SPT's) were conducted after encountering natural soil deposits (approximately 10 to 13 feet below the ground surface) and using an automatic hammer. Split-spoon samples were obtained at intervals of 2.5 feet to the bottom of each boring. Detailed logs of borings are presented in Appendix B. A bulk sample was obtained during the excavation of the pile caps to determine compaction requirements for the backfilling operation.

An engineer of Geotechnology provided technical direction during field exploration, observed drilling and sampling, assisted in obtaining samples, and prepared descriptive logs of the material encountered. The boring logs represent conditions observed at the time of exploration but have been edited as a result of the laboratory test data as appropriate.

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#### SET UP FOR GEOPHYSICAL SURVEYS

After finishing soil sampling at each boring, the bore holes were re-drilled and enlarged by using 6-1/4 inches inside diameter (I.D.) hollow stem augers to a depth of 15 feet from the ground surface. Eight inch diameter PVC pipe was installed to an approximate depth of 17 feet below the ground surface for use as temporary casing. After the temporary casing was installed, the bore hole was drilled to the termination depth using rotary wash drilling methods and a 7-7/8 inch diameter tri-cone roller bit. Access pipes for geophysical surveys consisting of 4-inch diameter PVC pipes were installed. The annular space between the bore hole and the 4-inch pipe was grouted. The access pipes were backfilled with grout after conducting three geophysical surveys.

#### LABORATORY TESTING

Laboratory testing was performed on the soil samples to determine index properties of the soil and recommended shear strength parameters for re-analysis of pile capacity. Moisture contents, Atterberg limits tests and sieve analyses were performed on selected samples. Results of these laboratory tests are presented on the boring logs and Appendix C. A proctor test was performed on the bulk sample. Summary results are presented in Appendix C.

#### SECTION IV - SUBSURFACE CONDITIONS

#### **STRATIGRAPHY**

Below the surficial 6 inches of top soil, generally 9.5 to 12.5 feet of silty clay fill overlies 10 to 18 feet of very loose to medium dense brown to gray silty sand with intermediate layers of soft, brown and gray clayey silt and silty clay. Below the silt sand, medium dense to dense gray to dark gray silty sand and fine to coarse poorly-graded and well-graded sand were encountered to boring termination at a depth of 50 feet.

#### GROUNDWATER

Groundwater levels were not observed in the borings due to rotary wash drilling methods being used. No groundwater was encountered while drilling with the flight augers to a depth of 15 feet below ground surface.

## RECOMMENDED SHEAR STRENGTH PARAMETERS

Soil strength parameters for long-term conditions, including cohesion and angle of internal friction were estimated based on the in-situ SPT values. Buoyant unit weight should be used in any computation of allowable pile capacity based on the assumption that the design

## APPENDIX B

DETAILED LOGS OF BORINGS B-16, B-21 AND B-23 BORING LOG: TERMS AND SYMBOLS

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Surface Elevation Completion Date: 9/22/03	a ve			0122102		3)		5	HEAF	RSTRENG	TH,	tsf	
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Medium dense, brown to gray, silty SAND - SM  9-9-9 SS5  Mecium dense, brown to gray, poorly-graded fine, SAND with silt - SP-SM  7-10-10 SS7  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  7-7-11 SS8  Drawn by: yell Ckd. by: Yell Particles (SAND) pate: 1g/15/01  ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAYL LOGGER  DWB DRILLER TAYL LOGGER		Stiff, brown to gray,	, sandy SILT - ML		1111	0.2.3	303	na wed nie		1. 1.11		11	
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Medium dense, brown to gray, slity SAND - SM  9-9-9 SS5  Medium dense, brown to gray, poorly-graded fine, SAND with slit - SP-SM  7-10-10 SS7  Medium dense, gray, poorly-graded fine, SAND, trace slit - SP  T-7-11 SS8  GROUNDWATER DATA  DRILLING DATA  ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  DWB DRILLER TAW LOGGER						201	001	105 0 102 5050 105 0 107 5050		tions or to		5 6 50 0 6 50	todot te
Medium dense, brown to gray, poorly-graded fine, SAND  9-9-9 SS5  Medium dense, brown to gray, poorly-graded fine, SAND  7-10-10 SS7  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  7-7-11 SS8  Drawn by, yew CKd. by, Yew Parties of Section 10, FEET  DWB DRILLING DATA  DRILLING DATA  ENCOUNTERED DURING DRILLING  WASHBORING FROM 10, FEET  DWB DRILLER TAW LOGGER  ST. OUR SENT ON ST. OUR SYNTEN.	20-				ЩЦ	2-0-4	334	. sa o sa a s	0 2 0	2002 52 5	**	5 8 50	505501 IS
Medium dense, brown to gray, poorly-graded fine, SAND with silt - SP-SM  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  T-7-11 SS8  Drawn by, yet CKd. by, Yew Date 925/03 Date: 14/5/b1  X FREE WATER NOT ENCOUNTERED DURING DRILLING WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  DWS STILUS COLUNSWEE.	20	Medium dense, bro	wn to gray, silty S	AND - SM				60 3 62 5 5				2 8 500	
Medium dense, brown to gray, poorly-graded fine, SAND with silt - SP-SM  Medium dense, gray, poorly-graded fine, SAND, trace silt - SP  GROUNDWATER DATA DRILLING DATA  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  DWB DRILLER TAW LOGGER						000	COE	-0.000000000		1 00 00 00 0		0 E 00	60,808 80 K 608 80
Medium dense, gray, pocriy-graded fine, SAND, trace sitt - SP  Medium dense, gray, pocriy-graded fine, SAND, trace sitt - SP  GROUNDWATER DATA  ERCOUNDWATER DATA  SS8  Drawn by: yew   Ckd. by: yew   Date: 10/.c/o3   Date: 10/.c						3-3-3	333	FIG. 18 609 91 63 1002001 1001 01 10		2 23 43 K	1000	OFFICE FOR	F 509 90 S 202 90
Medium dense, gray, pocriy-graded fine, SAND, trace sitt - SP  Medium dense, gray, pocriy-graded fine, SAND, trace sitt - SP  GROUNDWATER DATA  ERCOUNDWATER DATA  SS8  Drawn by: yew   Ckd. by: yew   Date: 10/.c/o3   Date: 10/.c										E 419 419 F	107		K 604 60
Medium dense, gray, pocriy-graded fine, SAND, trace silt - SP  Medium dense, gray, pocriy-graded fine, SAND, trace silt - SP  GROUNDWATER DATA SSR  Drawn by: year   CKd. by: Year   Date: 1q1, x103   Drawn by: year   CKd. by: Year   Date: 1q1, x103   Drawn by: year   Date: 1q1, x103   Date: 1q2, x103		· · · · · · · · · · · · · · · · · · ·			111	607	CCC	1000 101 1					0 200 80 0 400 80
Medium dense, gray, pocriy-graded fine, SAND, trace silt · SP  GROUNDWATER DATA  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  DWB CRILLER TAW LOGGER  COLUMNIC ONLY DIVISION ST. LOUIS · COLUMNIC ON	0.5		wn to gray, poorly	r-graded line, SANU		0-8-7	330	produce and it is		. 0 575 975 0			V 1992 199
Medium dense, gray, pocriy-graded fine, SAND, trace silt - SP  GROUNDWATER DATA  A DRILLING DATA  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  ONE STATE AND ENVIRONS STERLING STAND LOGGER	- 25-1	maran or on											0.5 8 505 50
Medium dense, gray, pocriy-graded fine, SAND, trace silt - SP  GROUNDWATER DATA  A DRILLING DATA  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAW LOGGER  ONE STATE AND ENVIRONS STERLING STAND LOGGER							1	5 53 555 5		11111	::::		5 195 50 5 105 50
GROUNDWATER DATA  SREE WATER NOT ENCOUNTERED DURING DRILLING  SILL SP  7.7-11 SS8  Drawn by: yew Crd. by: Yew Date: 9/25/03 Date: 16/15/03 Da						7-10-10	1557	2 24 25 2 3	• •	n 101 mais	100	20.5 50.50	2 505 00
SILL SP  GROUNDWATER DATA  DRILLING DATA  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET DWB DRILLER TAY LOGGER  DOTAWN DY, YEW CHO, BY, YOU PARTY OF THE PROPERTY OF T		18 January Strate	noody arad-d	fine CANID trace	111	4					500		6 100 10 6 100 15
GROUNDWATER DATA  DRILLING DATA  DRIVING DATA  DRIVE GLOCKS, by: Year   Cred. by: Year   Date (925/03)   Date: (10/15/03)    SERVE WATER NOT   6.25 AUGER   HOLLOW STEM   WASHBORING FROM 10 FEET   DWB DRILLER TAW LOGGER   ST. LOUIS - COLUNSWILE - TAW LOGGER		sit - SP	y, poeny-graded	mie, oatyu, uace			1			ear ear source gas ear source	500		e tokor e rokor
A STRILLING DATA  DRILLING DATA  Date: 10/15/01  Date: 9/25/03  Date: 10/15/01  Date: 9/25/03  Date: 10/15/01		470V 000000000000		3 * *		7-7-11	SS8					10x 9000	
X FREE WATER NOT ENCOUNTERED DURING DRILLING  6.25 AUGER HOLLOW STEM WASHBORING FROM 10 FEET DWB DRILLER JAW LOGGER  ST. FOUNT COLUMN STEM ST. FOUNT COLUM		PROGRAMMENT PRO		DOULEGO	DATA		د سد سال			CK'd. by: Yo	w	App'vd. t	ruis
ENCOUNTERED DURING DRILLING  WASHBORING FROM 10, FEET  DWB DRILLER TAW LOGGER  DWS DRILLER TAW LOGGER	<u>c</u>	SKOUNDWATER DA	114	DKILLING	DATA			Date: 9/25/0	3	Date: 19/15	103	Liul	6/13
ENCOUNTERED DURING DRILLING  WASHBORING FROM 10 FEET  DWB DRILLER TAW LOGGER  ONE SELECTION OF COLUMNING AND ENVIRONMENT OF THE PROPERTY OF TH	ng processi			<u>6.25</u> AUGER	HOLL	OW STEM				<b>TECH</b>	NO	LOC	Y. INC
OME COST OBILL DIG	ENCO	UNTERED DURING D	RILLING	WASHBORING FR	OM _10	) FEET			NGINE	ERING AND EN	VIRON	MENTAL	SERVICE
CME 55HT ORILL RIG				<u>DWB</u> DRILLER	TAW I	.OGGER							106
Earnay Floor				CME 55HT C	RILLF	₹IG			Ε.	airfay F	loo	d	
HAMMER TYPE Auto Control Struction				HAMMER TY	PE Au	to.							
Control Structi									CON	iu ui əli	uCl	uie	
REMARKS:	REM	ARKS:											
LOG OF BORING								LO	G O	F BOR	NG	: B-	21
Project No. 0713201.								1	Projec	ct No. 071	3201	.3211	

Confess Election			6.0		SHE	AR STRENG	TH, ts	
Surface Elevation	Completion Date: 9/22/03		ROST ROC		Δ - UU/2	O - QU/2		D - SV
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Dalum	DESCRIPTION OF MATERIAL  Completion Date: 9/22/03  Completion Date: 9/22/03				STANDARD P			
T-F-			(ASTM D 1586					
DESCR	IPTION OF MATERIAL	8	SE F			UE (BLOWS TER CONTE		001)
S Z	Medium dense, gray, poorly-graded fine, SAND, trace silt - SP (continued)		SPT E		PL   10 2		40	50 L
silt - SP (continue	d)					100 X 505 8060		
			6-10-10	559				04 8 604 804 01 0 000 000
						222 22 200		74 7 454 0 A
			12-11-8	SS 10	202 CON 204 C 4	Charles Steel St.	8	20 0 100 0 I
35 Hadium donce h	SAND CI				-,			
Medium dense, b	rown, silty SAND - SM					MARK BOOK NO.		
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					ter a tra comment to	3 102 8 103 10		5000 ES E 1
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GROUNDWATER	NATA DRILLI	NG DATA		1.	Drawn by: yaw Date: 9/25/03	Ord by ye		op'va. by Li
				<u> </u>	Date: 9/25/03	Date: 10/1.	1/03	rolli
GROUNDWATER E  X FREE WATER N ENCOUNTERED DURING	NOT <u>6.25</u> AUGER	HOLLO	OW STEN		Date: 9/25/03	OTECH	1703 NOI MIRONM	OGY, II
X FREE WATER	NOT <u>6.25</u> AUGER	HOLL	OW STEM		Date: 9/25/03	Date: 10/1.	1703 NOI MIRONM	OGY, II
X FREE WATER	NOT <u>6.25</u> AUGER DRILLING WASHBORING	HOLLO	OW STEN O FEET OGGER	) <u> </u>	Date: 9/25/03	Oale: 10//. OTECH NEFRING ANDEN ST. LOUIS - COLUM	NOI NOI IVIRONM SVILLE - K	OGY, II LOGY, II ENTAL SERVI MISAS CITY
X FREE WATER	OT <u>6.25</u> AUGER DRILLING WASHBORING <u>DWB</u> DRILLER	HOLLE FROM 19 TAW 1 T DRILL F	OW STEM O_FEET .OGGER RIG	<u> </u>	Date: 9/25/03	OTECH	NOI NOI IVIRONM SVILLE - K	OGY, IP LOGY, IP ENTAL SERVE ANSAS CITY
X FREE WATER N	OT 6.25 AUGER DRILLING WASHBORING  DWB DRILLER  CME 55H	HOLLE FROM 19 TAW 1 T DRILL F	OW STEM O_FEET .OGGER RIG	<b>]</b>	Date: 9/25/03  G GE GNG	Oate: 10/15 OTECH NEFRING AND EN ST. LOUIS - COLUN	NOI WIRONM SVELE - K	OGY, III

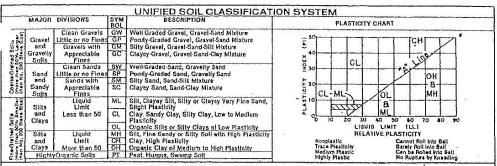
무면			GRAPHIC LOG	DRY UNIT WEIGHT (pd) SPT BLOW COUNTS CORE RECOVERY/ROD	SAMPLES	STANDARD F	0 1,5 2 PENETRATION ( (ASTM D 1586) LUE (BLOWS PE	
DEPTH IN FEET	DESCRIPTION OF	MATERIAL	0	RY L SPT ORE		PLI WA	TER CONTENT	, %
			ļ., .	ä o		10 2	0 30 4	0 50
	Topsoil - 6 inches FILL: brown, silty sand		XXX			7 27 C C C C C C C C C C C C C C C C C C		had be a see
						5 THE SCHOOL ST.		20202 202 0 504 7
			<b>****</b>			A 100 BORGE BORGE		MODELS NOT IN COST OF
						X 02 KEEK K 50	DESCRIPTION OF REAL PROPERTY.	10.000 KO 18 KO 1
			<b>***</b>	1,21		A 623 POSCS N 623		600 St. 6 600
- 5-						2 22 080 0 22		
			<b>***</b>			E NO DECEMBER		Date to a real
			<b>****</b>		***************************************	0 202 00000 5 200	1001 1002 24 2 2	Vers para pres
						0 212 01010 5 216		
			***					* 10 %
<b>5</b>			$\otimes \otimes$		3	0 200 0 302 2 302		2 202 20200 2020
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JAPIC TOTAL			$\otimes$			2 507 2 503 2 503 2 507 2 503 2 504		2 53 5050 5050
2 G			<b>****</b>			X 100 3 100 K 100	50 t 60 K/K/K 6	B 504 BOROL 10400
SAT.C			<b>***</b>			3 X X		X 600 80808 0000
TSC	Soft, brown, silty CLAY, trace fine	nand (CL)	<b>****</b>			T 100 T 100 T 100		
S ILLUST	Son, Glown, Siny CEAT, hace line	5400 - (CC)		1-2-1	SS1	<b>X</b>	20 000 000 0	
[ - 15 -							an man and a	
90						9 25 9 29 9 29		- 11 1 1 1 1 1 1 1
3				0-0-4	SS2	[4] [H		-1
اد					Estatu.	A fire a second	101 10101 10101 1	
न्	Soft, brown, clayey SILT - ML					A 505 0 501 0 505	207 20202 20205 20	
3				1-3-4	883	A 50505 FOR S 505	100 10 100 A 10 A 1	
Ö — 20 →	Loose, brown, silty SAND - SM		Ħ			2	KO DEG DOG K	8 63 8 80 B B 63
				CONTRACTOR OF THE PARTY OF THE			AN ENGLY SOME FO	* 100 C 100 X 20
<u> </u>				4-5-5	SS4	x 10201#1. x 201		N 100 O 100 E 20
NSN							61 B 61 B 600 B	x 202 0 205 E 20
ğ	Loose, brown, poorly-graded medi	um, SAND, trace gray		2.0.2	ccc			
- 25 -	sandy sitt - SP			3-2-2	SS5	1 <b>*</b> 2 × 1 × 1 × 1 × 1		A for a nor a so
CNA ZJ								0.000.000.000
	Dense to medium dense, gray, por medium, SAND - SP	orly-graded fine to		14-16-16	922		Total State of Red St	5 100 5 100 5 100 5 100 5 100 5 100
10/16/03	tribuloni, dalab - di	W					507 5 507 \$1750 5	2 500 X 500 X 500 2 500 X 500 X 50
568		1.				P	505 8 505 K 505 K	2 101 1 102 1 10
99		1 6 M		7-9-8	SS7	- sea sea se		
830			1.7.65			Towns have	lova by Ma S	The state of the state of
90 0	GROUNDWATER DATA	DRILLING I	DATA			Drawn by, yaw Date: 9/25/03	Date: 10/15/0	
GTINC 06:8301	X FREE WATER NOT	6.25 AUGER	HOLLO	W STEM			OTECHNO	
g ENCO	OUNTERED DURING DRILLING	WASHBORING FRO				ENGI	VEERING AND ENVIRO	NMENTAL SERVICES
XX.		DWB DRILLER Y					ST. LOUIS + COLLINSVALLE	· KANSAS CITY
132-FAIRFAX GPJ		CME 55HT DE						
35		HAMMER TYP	E Aut	<u> </u>			Fairfax Floontrol Struc	
≅ REM	ARKS:							
						100	or nonui	
MBR						LOG	OF BORING	3: B-23

STANDARD PENETRATION	() - SV
Datum	U - 04
DE LEGISLA STANDARD PENETRATION  LEGISLA STANDARD PENETRATION  (ASTM D 1586)	2 <sub>1</sub> 0 2 <sub>1</sub> 5
T.E.   Y   E Q E   X   (AS IM D 1986)	RESISTANCE
京田 DESCRIPTION OF MATERIAL   常   Smith   M N-VALUE (BLOWS PI	-R FOOT)
DESCRIPTION OF MATERIAL	T. %
	40 50
Dense to medium dense, gray, poorly-graded fine to medium, SAND - SP (continued)	
7-7-5 SS8	
Loose to medium dense, gray, poorly-graded fire, SAND, trace gray silty sand - SP	
34-5 SS9 1	
	PT 5 3.
3-4-7 SS10 A	to the term are
3 M AAA MA BA B B N A A A A A A A A A A A A A A A	107 E 105 E09 E09 103 E08 E 105 E09
Med-um dense to dense, gray, poorly-graded medium, 6-7-5 SS11	
40 SAND with silt - SP-SM trace fine gravel	
6-16-12 SS12	
6-16-12   SS12   A	
7-11-12   5513	100 10000 100 0
- 45	
99-8 SS14 A . •	
Modium dense, gray, well-graded medium to coarse	
sand, trace fine gravel - SW 10-10-8   SS15   A	
50 Boring terminated at 50 feet	
- ID File Lining	101 total total
- 55 -	1
	63 665 65 55 63 665 65 75
	1
GROUNDWATER DATA  DRILLING DATA  Date: 9/2503  Date: 9/2503  Date: 9/2503	App'vd. by:
X FREE WATER NOT 6.25 AUGER HOLLOW STEM	2 1/11/12
A STREE WATER NOT ENCOUNTERED DURING DRILLING  MASHBORING FROM 13.5 FFET  MASHBORING FROM 13.5 FFET  Date: 9/25/03 Date: 10/15/0  MASHBORING FROM 13.5 FFET	OLOGY, INC
X. FREE WATER NOT ENCOUNTERED DURING DRILLING WASHBORING FROM 13.5 FEET  DWB DRILLER YAW LOGGER  Date: 9/25/03 Date: 10/15/0  Date: 9/25/03 Date: 10/15/0  Date: 9/25/03 Date: 10/15/0  GEOTECHN  ENGINEERING AND ENVIR	OLOGY, INC
ENCOUNTERED DURING DRILLING  X FREE WATER NOT ENCOUNTERED DURING DRILLING  WASHBORING FROM 13.5 FEET  DWB DRILLER YAW LOGGER  CME 55HT DRILL RIG  DRICLING DATA  Date: 19/25/03  Date: 19/25/0	OLOGY, INC. ONMENTAL SERVICES E · KAHSAS CITY
ENCOUNTERED DURING DRILLING  MASHBORING FROM 13.5 FEET  DWB DRILLER YAW LOGGER  Date: 19/25/03 D	OLOGY, INC. ONMENTAL SERVICES E - KAHSAS CITY  Od
A FREE WATER NOT ENCOUNTERED DURING DRILLING BATA  LESS AUGER HOLLOW STEM WASHBORING FROM 13.5 FEET DWB DRILLER YAW LOGGER CME 55HT DRILL RIG HAMMER TYPE AULO  CONTROL STRUCT  Fairfax Flo Control Struct  REMARKS:	OLOGY, INC. OMMENTAL SERVICES E - KANSAS CITY  Od  cture
EROUNDWATER DATA  DRILLING DATA  Date: 9/25/03  Date: 10/15/0  Date: 9/25/03  Date: 10/15/0  Date: 9/25/03  Date: 10/15/0  Date: 9/25/03  Date: 10/15/0  GEOTECHNI  WASHBORING FROM 13.5 FEET  DWB DRILLER YAW LOGGER  CME 55HT DRILL RIG  HAMMER TYPE Auto  Control Struct  REMARKS:  CONTINUATIO	OLOGY, INC. OMMENTAL SERVICES E - KANSAS CITY  Od Cture  ON OF
A FREE WATER NOT ENCOUNTERED DURING DRILLING BATA  LESS AUGER HOLLOW STEM WASHBORING FROM 13.5 FEET DWB DRILLER YAW LOGGER CME 55HT DRILL RIG HAMMER TYPE AULO  CONTROL STRUCT  Fairfax Flo Control Struct  REMARKS:	OLOGY, INC. OMMENTAL SERVICES E - KANSAS CITY  Od Cture  ON OF

BORING	OG: TE	RMS A	IND SYME	
' GENERAL NO	TES		LEGEN	D
Information on each boring log is a face conditions based on soil or re- tained from the field as well as from samples. The strata lines on the logs	compliation of subsur- ock classifications ob- n laboratory testing of may be approximate or	CS GB	Continuous Sampler Grab Sample Taken From Wash Water Return	Auger Cultings Or
the transition between the stata may distinct. Water level measurements served at the times and places indice time, geologic condition or construct.  Retailve composition and Unified & nations are based on visual estimate only. If laboratory tests were perform.	refer only to those ob- ited, and may vary with ion activity. If Classification desig- is and are approximate and to classify the soil.	NX 100 42	NX Rock Core with Perce Given in Adjacent Column	
the unified designation is shown in p 3. Value given in Unit Dry Weight/SPT of dry weight in pounds per cubic foot, in ple designation, or blows per 6-inch in a SS sample designation.	Column is either a unit fadjacent to a ST sam-	PST	Three Inch Diameter Pisto Split Spoon Sample (Stan	
ABBREVIATI	ONE		Sp. 1	
UU/2 Shear Strength from Unconsc Triaxial Test (ASTM D2850)	olidated - Undrained	ST	Three Inch Diameter Shel	by Tube Sample
OU/2 Shear Strength from Unconflict Test (ASTM D2166) SV Shear Strength from Field Va	500 miles (50 miles)		Sample Not Recovered	s 2
PL Plastic Limit (ASTM D4318) LL Liquid Limit (ASTM D4318)	•	SV	Field Vane Test	
			I IVING RECORD	
NOTES: 1. To evoid demage to sampling Isolo 2. Vertice (Biox Count) is the standar to drive a spill spoon the last two of th may be shown as 4779 in Unit Dry We RELATIVE COMPOSITION		RENGTH	OF COHESIVE S	OILS
Trace	Consistency	Undrained 5h Strength Tor Per Sq. Ft.	is Fleld Test	Approximate N-Value Range
			Thumb will penetrate	
DENSITY OF GRANULAR SOILS			Thumb will penetrate Thumb will penetrate	
Descriptive Term: N-Value			Thumb hardly Indents	
Very Loose	Very Still	1.01 to 2.00	Thumb will not Inden	t soll, but readily rall 16-30
Very Dense > 50	SOIL	GRAIN SIZE		
12" 3"	₩" Ü.S. S1	FANDARD SIEVE	40 200	
BOILDERS CORRLES	GRAVEL		EDIUM FINE	SILT CLAY
300 76.2	19.1 4.76	2.00 SIZE IN MILLIME	0.42 0.074	-005
	SOIL	STRUCTU	RE	
Calcareous — Having appreciable q	uantities of carbonate		— Inclusion less than 1/8	
Fissured — Containing shrinkage Illied with fine sand or si vertical.	or relief cracks, ofte.	n Pocket s	- Inclusion of material of smaller than the diame rered - Soll samples co	eter of the sample.
				moosed of alternation
Slickensided — Having planes of slick and glossy. The d ness depends upon the s and the ease of breaking	earse of slickensided	f. Intermi	layers of different soil xed — Soil samples compo ent soil types and a lay ture is not evident.	types.

GEOTECHNOLOGY ENGWEZING AND ENVIRONMENTAL SERVICES EAINT LIGHEL, INSCOURT

PLATE



### VISUAL DESCRIPTION ORITEDIA .

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	Strong	Will not crumble or break with finger pressure	ML	cannot be
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**Geotechnical Calculations** 

# EXHIBIT A-7.15 Fairfax-Jersey Creek Flood Wall Pile Foundation Documentation

### Appendix 4

### Fairfax-Jersey Creek Flood Wall Documentation

## Development of the Ultimate Resistance of the Piles Below the Floodwall: Station 287+85 to 302+32.

The geometry of the existing flood wall can be found on 0 & MM Plate 38 of reference 11. The 17'-9" high stem of the floodwall sits 12'-6" back from the riverside face of the keyed riverside pile cap. The total width of the pile cap is 19'-3". In a cross section through the wall, three driven 15.5-inch diameter concrete piles support the pile cap. Nondestructive subsurface investigations concluded that one area of the floodwall has piles with a length of 19 feet below the pile cap.

The structural engineers needed ultimate geotechnical resistance of the driven piles. The subsurface investigation boring results were used to determine a cohesionless strength of the foundation sands adjacent to and below the piles. Both side resistance and end bearing was considered to determine the ultimate geotechnical resistance of the piles.

Side Resistance. The side resistance,  $Q_s$ , that develops adjacent to the piles is dependent on the construction placement procedure, the correlated soil strength, the length and diameter of the piles, and the pore pressures developed during loading along the piles.

The loading conditions include end of construction and varying river stages.

The side resistance calculated for a given increment of depth  $\Delta l$  below the pile cap was computed using the equation  $\Delta SR = f SR_z * \Delta AREA$  where  $f SR_z$  is the side resistance strength of the sand at depth z below the ground surface. The side resistance of the sand acts upon  $\Delta$ AREA of the pile.  $\Delta$ AREA is the perimeter of the piles for the length  $\Delta$ l or  $\Delta$ AREA =  $\pi$  \* d \*  $\Delta$ l with d being the diameter of the pile. The side resistance of the sand is dependent on the correlated effective friction angle of the sand at depth z. The lateral earth forces acting upon the incremental  $\Delta l$  and the effective pore pressure acts upon the incremental area of the pile,  $\Delta$ AREA. The pore pressure is calculated based on the river stage, or head (H) acting on the flood wall and the sand foundation. The pore pressures were calculated using a simple two dimensional flow net based on the cross section of the flood wall and its foundation. The foundation is mostly sand with very little to no impervious blanket. The flow net provided equipotential drop lines from full head. These lines were used to determine the pore pressures along the piles for various river stages.

The magnitude of the effective pressure acting along the sides of the piles is sensitive to the placement techniques used to construct the piles. The piles were driven. The magnitude of the compressional coefficient of pressure used for analysis,  $K_c$ , was set to 1.0. EM 1110-2-2906 allows 1.0 to 2.0. The effective lateral pressure was

reduced by the pore pressure developed for each river stage used in the analysis. The effective lateral pressure was multiplied by the effective friction angle for sand acting on a concrete surface,  $\delta'$ . The values suggested in EM 1110-2-2906 ranged from  $0.9\phi'$  to  $1.0\phi'$ . The values used for the analysis are more conservative than the EM and are consistent with that suggested by Reese. The value  $\delta'$  used was  $\phi'$ -5°. DSR

The incremental side resistance,  $\Delta$ sR, was computed as  $f_s$  \*  $\Delta$ AREA or  $[(\sigma_{tz} - \mu_{wz})$  \*  $K_c]$  \*  $[tan(\delta')$  \*  $\pi*d*(\Delta l_z)]$ .

Where  $\sigma_{tz}$  is the total pressure at depth z; and  $\mu_{wz}$  is the pore pressure at depth z; and  $\Delta l_z$  is the increment length of pile at depth z.

The spreadsheet calculates the resistance for each increment and adds the increments as the depth z increases. A total ultimate capacity is provided at the bottom for the total length of the pile.

End Bearing Resistance. The end bearing pressure acting on the area below the pile provides the end bearing capacity. The end bearing capacity is dependent on the effective friction angle of the sand, the effective overburden pressures below the pile and the cross sectional area of the bottom of the pile.

 $Q_t = q_{br} * A_t$  below pile for depth z

Where  $q_{br}$  =  $\sigma_{\nu}{}'$  \*  $N_q$  .  $N_q$  is the expected value of the bearing capacity factor dependent of the overburden

surcharge loading (depth of soil) and the area of the bottom of the pile,  $A_t$ , is  $\pi$  \*  $(d/2)^2$ , with d being the diameter of the pile.

The bearing capacity factor used the mean values of Figure 4-4. The equation used in the spreadsheet was  $N_q = 0.8158 \, * \, e^{(0.1165\varphi^*)} \, .$  The values used for  $\sigma_v^*$  were based on the total overburden pressure less the pore pressures,  $\sigma_{vz}t \, - \, \mu_{wz}, \, \text{developed for each river stage}. \quad \text{The pore pressure was determined using the flow net}.$ 

<u>Ultimate Pile Capacity</u>. The ultimate capacity of the pile is determined by adding the side ressitance and the end bearing ressitance.

Results of the analysis. The results are provided for the landside, middle and riverside piles. A series of results are provided for the mean, mean - 1 standard deviation, mean + 1 standard deviation and for the one third \$\phi'\$ strength selection of the friction angle at the base of the piles. The friction angle along the sides of the piles varied with depth dependent on the blow counts taken. These values were also adjusted to provide mean, mean-1, mean+1 and one third strength values with depth. The results were provided for height of water on the flood wall of 8, 13 and 18 feet.

KCMOKS - FF-JC. FLOODWALL

Per EM 1110-2-2906; Dated 15 Jan 1991 P. 4-11

Quit= Qs+Qt

Qs = shall resistance

Qt = tip resistance

Qs=fsAs ; fs= average unit skin resistance
ASR2

for Kor' tan S

Use  $f_s$  calculated to a maximum value act some critical depth  $D_c = 10B - loose soils$   $D_c = 15B - mad dense soils$   $D_c = 20B - dense soils$ 

Or' = 8'D for DCDC

CV = 8' Dc Ser D>Dc

K = lateral earth Bressure coefficient

From Table 4-3 p. 4-12

Value of S -> Concrete Pile S varies from 0.9\$ to 1.0\$

Per Ruse use \$9-5° = S more conservative

than 0.9\$

Values of K Table 4-4

For Sand Ke ~ 1.0 to 2.0; Ke ~ 0.5 to 0.7

Congressional

7-43

FF- Jc (1)

KCMOKS TERS STUDY FT-JC FLOODWALL Locker EC-GD Nov 15, 2004

ENO BEARNO

DESIGN PURPOSES USE YNEAR INCREASE TO DE THEN USE CONSTANT BELOW THAT

2 sr = 50" Ng

Mg from Fig 4-4

Limit OV = 8'D for DeDe & OV = 8'De for D> De

Using De = 15B where . B = 15.54

De= (15.5) \* 15 = 19.4' Below Pile Cop

Pile cop base thickness = 3'
Limiting depth below grand Dc: 19+3 = 22' (Design)

The limiting depth control was ignored for two reasons:

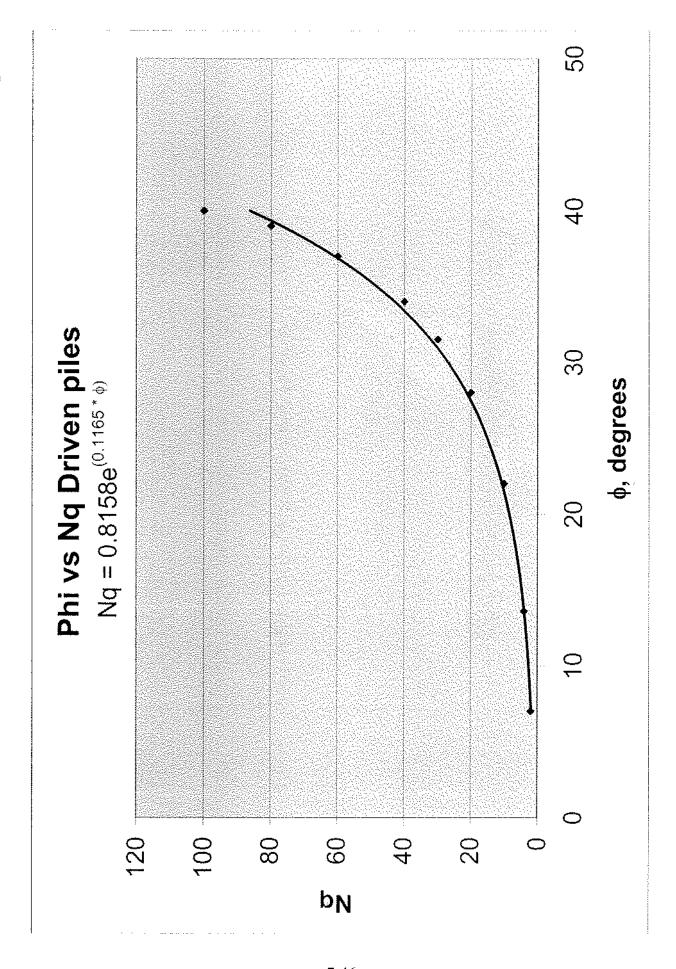
- i) Depth of Pilo = 191 2 22'
- 2) It is a requirement for DESIGN, we are studying the existing conditions.

10/5/2004 Lock EC-GD

Ref ETL 1110-2-556 date 28 May 1999

Use Variation of  $\phi'$  parameter of 10% Sta Dev =  $\sigma_d = V * E(\phi')$ 

Vertical Capacity of pile = Side Resist + End Bering = (2 \* Perinder + h) + 5' Ng = [(T' + tan p')(\text{rdh})] + [\text{o'} \* Ng]



Risk-Based Analysis in Geotechnical Engineering for Support of

ETL 1110-2-556

Planning Studies " 28 May 99

> Table 1 provides a summary of typical reported values for the coefficients of variation of commonly encountered geotechnical parameters. More detailed comment regarding the observed variability of relevant parameters is provided in the subsequent sections.

Table 1			V= 5 E(c)
Coefficients of Variation	n for Geotechn	ical Parameters	E(c)
Parameter	Coefficient of Variation, percent	Reference	(= V * E(c)
Unit weight	3 4 to 8	Hammitt (1966), cited by Harr (1987) assumed by Shannon and Wilson, Inc., and Wolff (1994)	
Drained strength of sand φ'	3.7 to 9.3	Direct shear tests, Mississippi <b>River Lock</b> and Dam No. 2, Shannon and <b>Wilson, Inc.,</b> and Wolff (1994) Schultze (1972), cited by Harr (1987)	Use 10% = V
Drained strength of clay φ'	7.5 to 10.1	S tests on compacted clay at Cannon Dam, Wolff (1985)	
Undrained strength of clay s <sub>u</sub>	40 30 to 40 11 to 45	Fredlund and Dahlman (1972) cited by Harr (1987) Assumed by Shannon and Wilson, Inc., and Wolff (1994) Q tests on compacted clay at Cannon Dam, Wolff (1985)	
Strength-to-effective stress ratio $\mathbf{s_u}$ / $\mathbf{\sigma'_v}$	31	Clay at Mississippi River Lock and Dam No. 2, Shannon and Wilson, Inc., and Wolff (1994)	ŕ
Coefficient of permeability k	90	For saturated soils, Nielson, Biggar, and Erh (1973) cited by Harr (1987)	
Permeability of top blanket clay <sup>k</sup> b	20 to 30	Derived from assumed distribution, Shannon and Wilson, Inc., and Wolff (1994)	
Permeability of foundation sands k <sub>f</sub>	20 to 30	For average permeability over thickness of aquiter, Shannon and Wilson, Inc., and Wolff (1994)	
Permeability ratio k <sub>f</sub> / k <sub>b</sub>	40	Derived using 30% for k, and k <sub>s</sub> ; see Annex B	
Permeability of embankment sand	30	Assumed by Shannon and Wilson, Inc., and Wolff (1994)	

# Use 10% = V

### **Unit Weight of Soil Materials**

The coefficient of variation of the unit weight of soil material is usually on the order of 3 to 8 percent. In slope stability problems, uncertainty in unit weight usually contributes little to the overall uncertainty, which is dominated by soil strength. For stability problems, it can usually be taken as a deterministic variable in order to reduce the number of random variables and simplify calculations. It

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where

 $c_{\star}$  - adhesion between the clay and the pile

 $\alpha$  - adhesion factor

c - undrained shear strength of the clay from a Q test

The values of  $\alpha$  as a function of the undrained shear are given in Figure 4-5a.

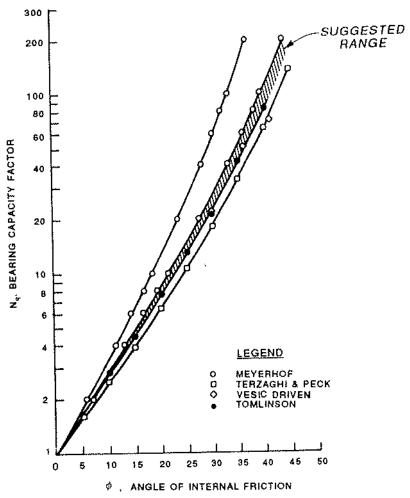


Figure 4-4. Bearing capacity factor

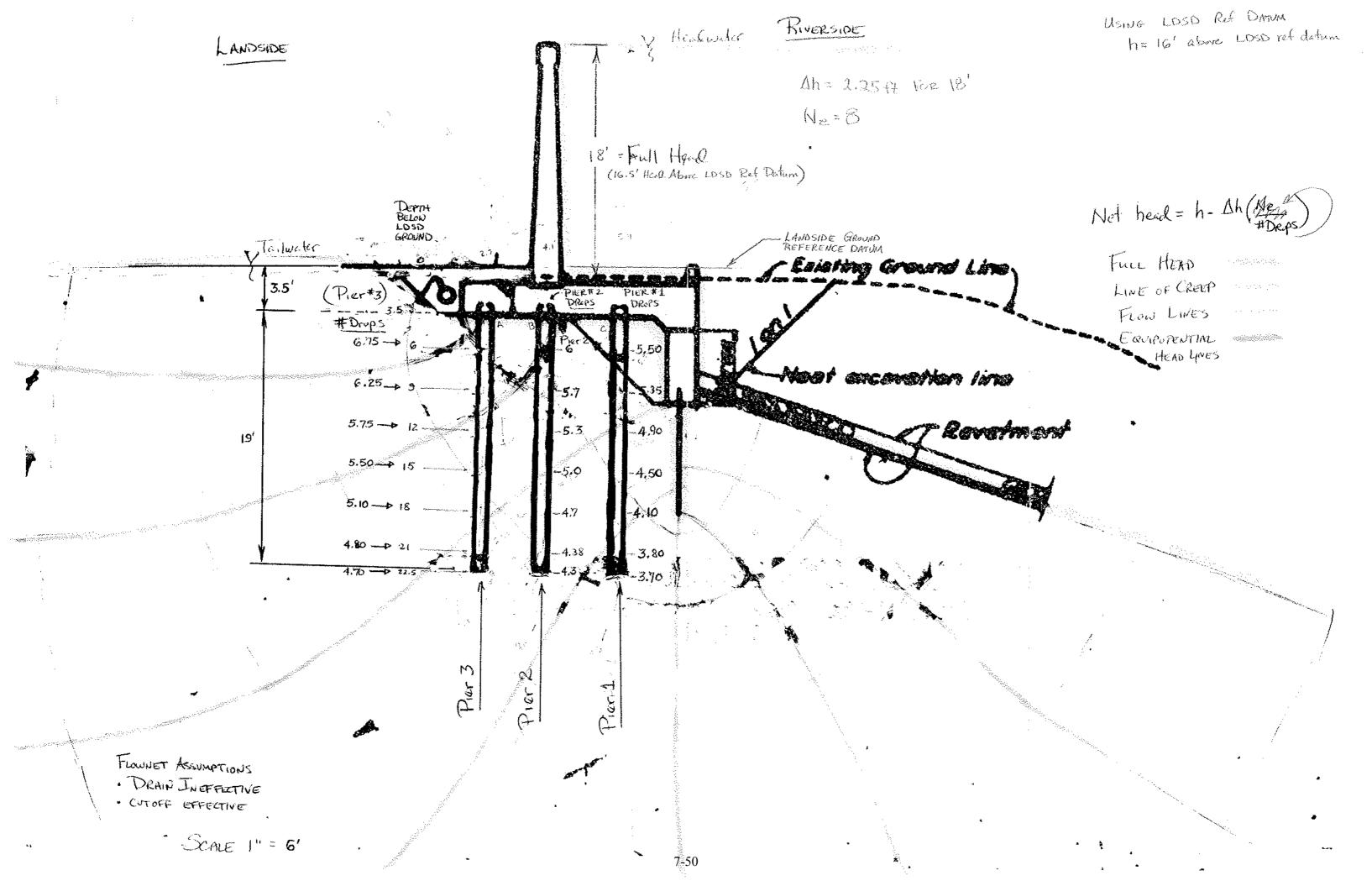
An alternate procedure developed by Semple and Rigden (Item 56) to obtain values of  $\alpha$  which is especially applicable for very long piles is given in Figure 4-5b where:

$$\alpha = \alpha_1 \alpha_2$$

and

$$f_s = \alpha c$$

### EXHIBIT A-7.16 Fairfax-Jersey Creek Flood Wall Flownet



"te Capacity of Driven Piles Chapter 3 Ultim effective overburden pressure at the point in question, D

= the friction angle between the soil and the pile wall.

A value of K of 0.8 was recommended for open-ended pipe piles, that are driven unplugged, for loadings in both tension and compression. A value of K of 1.0 was recommended for full displacement piles. In the absence of data on 8, Table 3.1 was recommended as guidelines only for siliceous soil.

Equation 3.9 implies that the value of fincreases without limit; however, Table 3.1 presents guidelines for limiting values.

TABLE 3.1. Guideline for Side Friction in Siliceous Soil

		Limiting $f$ ,
Soil	$\delta$ , degrees	Kips/ft <sup>2</sup> (kPa)
Very loose to medium, sand to silt	15	1.0 (47.8)
Loose to dense, sand to silt	for β=22°, 20 ← ως → 1.4 (67.0)	7. 1.4 (67.0)
Medium to dense, sand to sand-silt	25 £ 6: 25 1.7 (83.1)	<b>→</b> 1.7 (83.1)
Dense to very dense, sand to sand-silt	30 fr 8=28 2.0 (95.5)	2.0 (95.5)
Dense to very dense, gravel to sand	35	2.4 (114.8)

# 3.3.5 End Bearing in Cohesionless Soil

For end bearing in cohesionless soils, API recommends the following.

APILE Plus 3.0 for Windows

m Piles 3-13 Chapter 3 Ultimate Capacity of i

 $q = \overline{p}_o N_q$ 

where

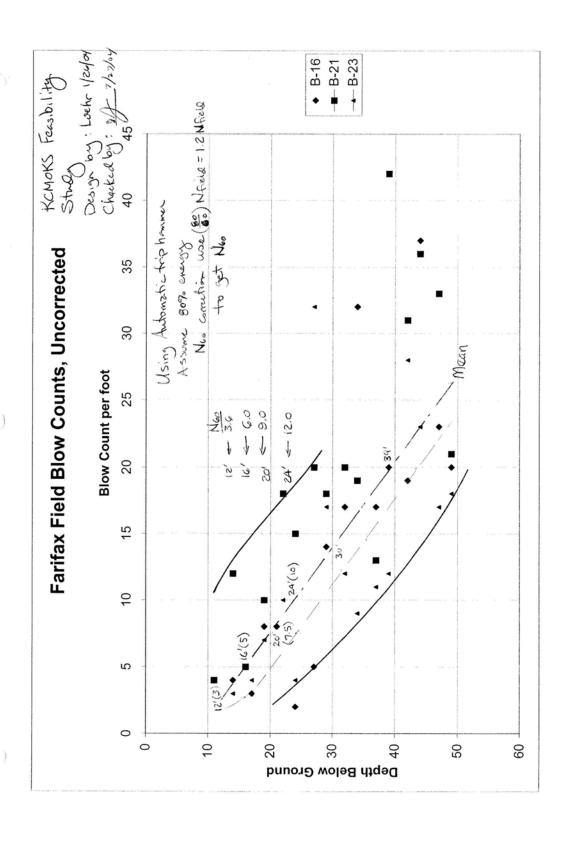
 $\overline{p} = \text{effective overburden pressure at pile tip, and } N_q = \text{bearing capacity factor.}$ 

Table 3.2 was recommended as a guideline only for siliceous soil.

TABLE 3.2. Guideline for Tip Resistance in Siliceous Soil

Soil	$N_{Q}$	Limiting q, kips/ft <sup>2</sup> MPa)
Very loose to medium, sand silt	' ∞	40 (1.9)
Loose to dense, sand to silt	12 - 6-22" -> 60 (2.9)	→ 60 (2.9)
Medium to dense, sand to sand-silt	20 < \$=25°> 100 (4.8)	→ 100 (4.8)
Dense to very dense sand to sand-silt	40 🗢 5 = 28° 🛶 200 (9.6)	200 (9.6)
Dense to very dense, gravel to sand	50	250 (12.0)

the description of those in the tables and that the design parameters are not suitable for these soils. Examples are loose silts, soils containing large amounts of mica or volcanic grains, and calcareous These latter soils are known to have substantially lower The API publication points out that many soils do not fit design parameters. Drilled and grouted piles may have higher capacities than driven piles in calcareous soils. APILE Plus 3.0 for Windows



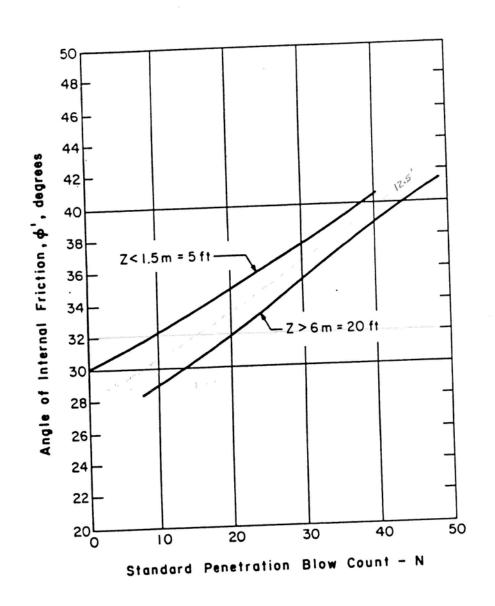
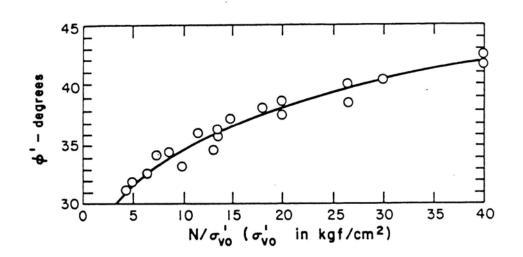
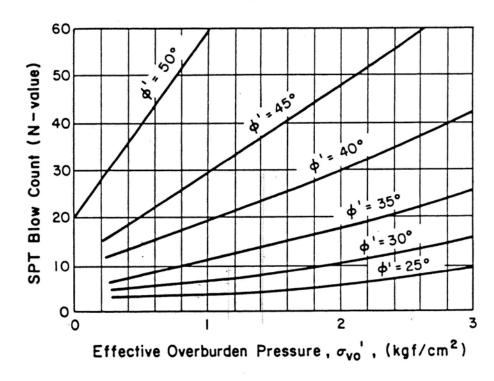


Fig.13 Relationship between Angle of Internal Friction of Cohesionless Soils and SPT Blow Count, (After Sowers, 1979).

Ref: "Shear Strength Correlations for Geotechnical Engineering". Duncan, Horz, Yang; August, 1989



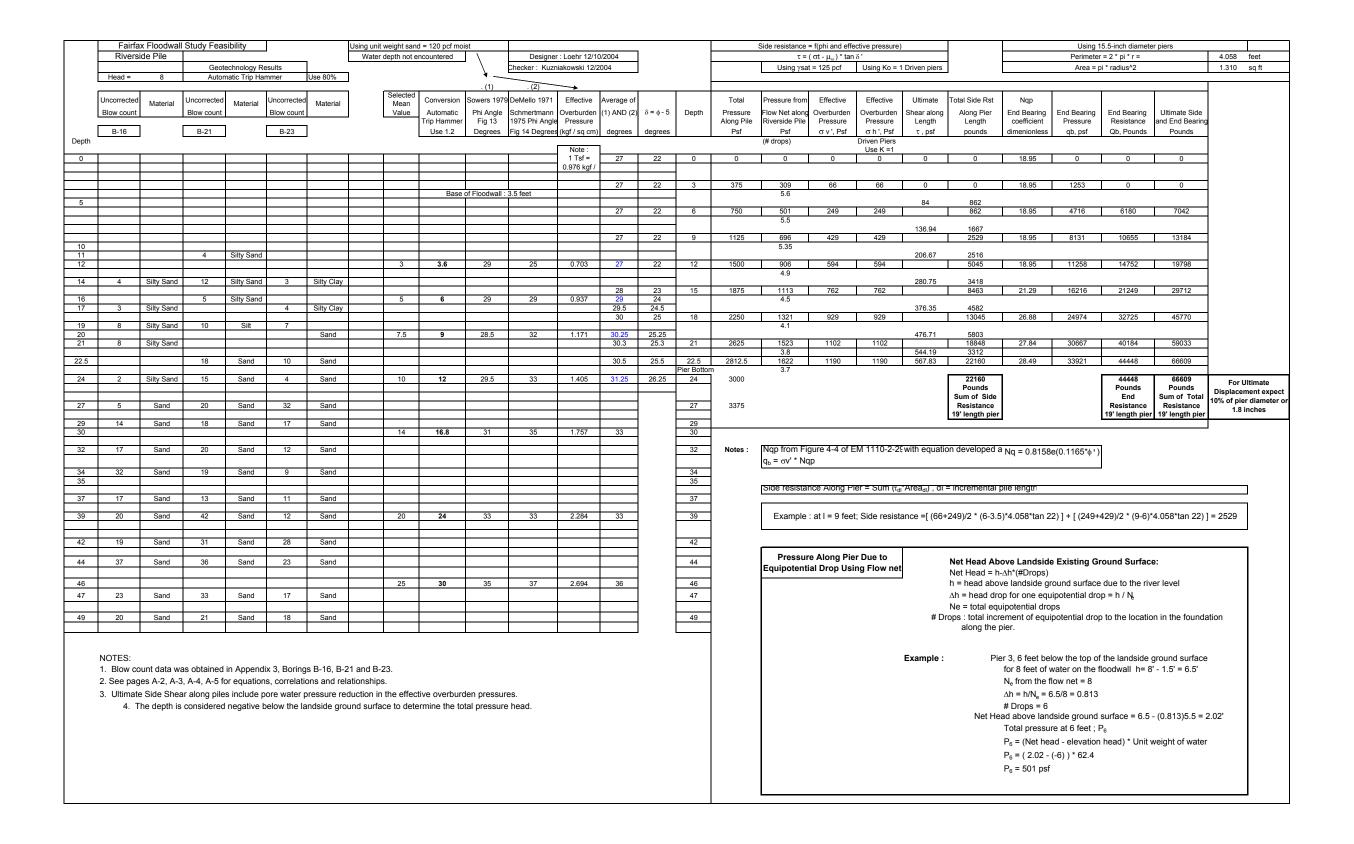
(a) Relation between  $\phi'$  and N/ $\sigma'_{vo}$ , (After Parry, 1977).



(b) Relationship among  $\varphi'$  , SPT-N and  $\sigma'_{VO}$  , (After DeMello, 1971 and Schmertmann, 1975).

Fig.14 Relationship among Overburden Pressure,  $\sigma_{VO}^{I}$ , Blow Count, N, and Peak Friction Angle,  $\phi'$ , for Sands.

### **EXHIBIT A-7.21**



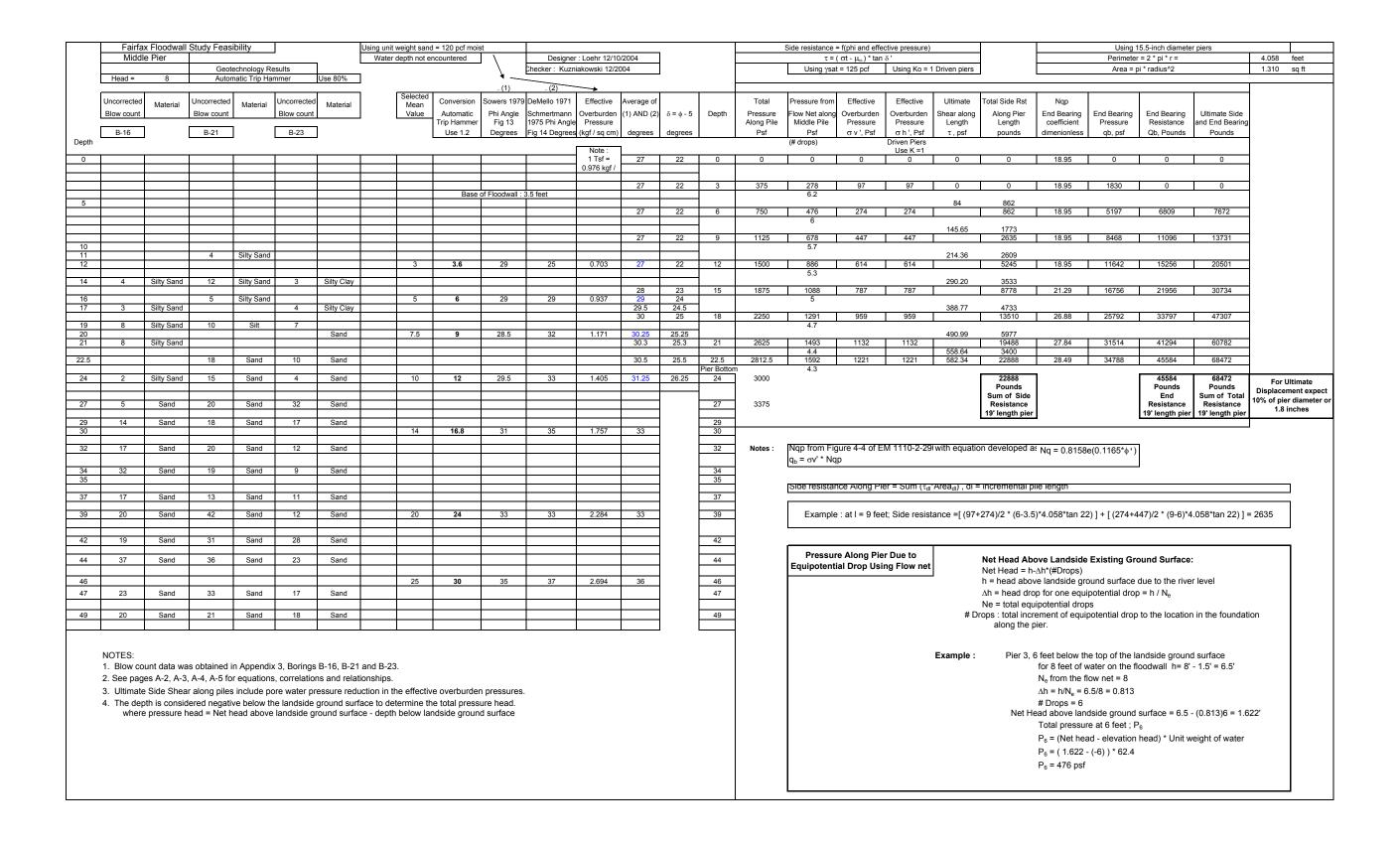
### **EXHIBIT A-7.21 (Continued)**

Riverside Pile  Water at TOW Head =13  Uncorrected Blowcount  B-16  Depth  0		echnology Rematic Trip Har	Uncorrected	Use 80%	Water depth	not encounter	ed	Checker: Kuzr	r : Loehr 12/10 niakowski 12/2					τ = ( Using γsat	ot - μ <sub>ω</sub> ) * tan δ = 125 pcf		= 1 - sin φ'				= 2 * pi * r = i * radius^2		4.058 feet 1.310 sq ft
Uncorrected Blowcount Material  B-16  Depth	Uncorrected Blowcount	natic Trip Har	Uncorrected		Coere		(1)	•	nakowski 12/2	2004	ļ			Using ysat	= 125 pcr	Using Ko	= 1 - sin φ	<u>l</u>		Area = p	i " radius"2		1.310 sq π
Blowcount B-16 Depth	Blowcount	Material			CSEIE		(1)																
Blowcount B-16 Depth	Blowcount	Material				cied		. (2)	F# #			1	<b>-</b>	In ( I	·· I	-« ··	I	0.1 5	I N			ı	
B-16 Depth			Blowcount	Material	Me			79 DeMello 1971 Schmertmann	Effective Overburden	Average of (1) AND (2)	$\delta = \phi - 5$	Depth	Total Pressure	Pressure from Flow Net along	Effective Overburden	Effective Overburden	Ultimate Shear along	Side Resistance Along Pier	N <sub>qp</sub> End Bearing	End Bearing	End Bearing	Ultimate Side	
Depth	B-21	•			Val	Trip Ha		1975 Phi Angle	Pressure	(1)71140 (2)	0 4 0	Вери	Along Pile	Riverside Pile	Pressure	Pressure	Length	Length	coefficient	Pressure	Resistance	and End Bearing	
	<u> </u>		B-23			Use	1.2 Degrees	Fig 14 Degrees	(kgf / sq cm)	degrees	degrees		Psf	Psf	σv', Psf	σh', Psf	$\tau \ ,  \text{psf}$	pounds	dimenionless	qb, psf	Qb, Pounds	Pounds	
0									Note :	1						Driven Piers Use K =1							
									1 Tsf =	27	22	0	0	0	0	0	0	0					
									0.976 kgf /														
							Ton of Bile	251		27	22	3	375	402	0	0		0					
5							Top of Pile :	3.5				3.5		5.6			31	310					
										27	22	6	750	599	151	151		310	18.95	2868	3759	4069	
														5.5			96	1173					
10										27	22	9	1125	799	326	326		1483	18.95	6173	8808	9572	
10	4	Silty Sand												5.35			161	1964					
12					3	3.	<b>3</b> 29	25	0.703	27	22	12	1500	1027	473	473		3448	18.95	8967	11750	15198	
14 4 Silty Sand	12	Silty Sand	3	Silty Clay	+		+	+				-		4.9			227	2769					
				,,						28	23	15	1875	1250	625	625		6217	21.29	13310	17440	23657	
16 Silty Sand	5	Silty Sand	4	Silty Clay	5	6	29	29	0.937	29 29.5	24 24.5			4.5			312	3799					
				,,						30	25	18	2250	1473	777	777		10016	26.88	20886	27368	37384	
19 8 Silty Sand 20	10	Silt	7	Sand	7.	5 9	28.5	32	1.171	30.25	25.25			4.1			403	4901					
21 8 Silty Sand								<u> </u>		30.3	25.3	21	2625	1687	938	938		14917	27.84	26107	34210	49126	
22.5	18	Sand	10	Sand				+	<del>                                     </del>	30.5	25.5	22.5	2812.5	3.8 1790	1023	1023	465	2833 17750	28.49	29143	38187	55937	
														3.7	- 1		•	17750			38187	55937	For Ultimate
24 2 Silty Sand	15	Sand	4	Sand	10	0 12	29.5	33	1.405	31.25	26.25	24						Pounds Sum of Side			Pounds Sum of Side	Pounds Sum of Side	Displacement exp
																		Resistance			Resistance	Resistance	10% of pier diamete 1.8 inches
27 5 Sand	20	Sand	32	Sand				1				27						19' length pier			19' length pier	19' length pier	
	<ol><li>Ultimate</li></ol>	e Side Shea	ar along pile	es include p		ssure reduc	nships. tion in the effec surface to dete							Side resistan	ce Along Pie	er = Sum (τ <sub>d</sub>	*Area <sub>di</sub> ) , dl :	= incremental p	oile length				
														Example	: at I = 9 feet	t; Side resis	tance =[ (0+	151)/2 * (6-3.5)	*4.058*tan 22	2)]+[(151+3	26)/2 * (9-6)*4	I.058*tan 22)]	= 1483
																	1						
														Pressure Equipotentia	e Along Pier al Drop Usir			Net Head Abo Net Head = h- h = head abov Δh = head dro Ne = total equ ops : total incre along the p	Δh*(#Drops)  ve landside gr  p for one equ  iipotential dro  ement of equi	ound surface ipotential drop	due to the rive	er level	ation
																		Net Head	for 13 feet of $N_e$ from the final $\Delta h = h/N_e = 1$ # Drops = 5.8 d above lands Total pressure.	water on the low net = 8 1.5/8 = 1.437 5 side ground sure at 6 feet; P et head - elev (-6)) * 62.4	floodwall h=  5  urface = 11.5	ndside ground 13' - 1.5' = 11. · (1.4375)5.5 = Unit weight of	3.60'

### **EXHIBIT A-7.21 (Continued)**

F			I Study Feasib	oility			Using unit weigl			st			2/222				Side resistance			)	_			5.5-inch diamete	r piers	1050
	Riversi	ide Pile	Cont	echnology R	oculto	1	Water depth	n not en	countered		Designer Checker: Kuzr	r : Loehr 12/1					τ = Using γsa	( σt - μ <sub>ω</sub> ) * tan		= 1 - sin φ'	4			= 2 * pi * r = i * radius^2		4.058 feet 1.310 sq ft
١	ater at TO	W Head =18		natic Trip Ha		Use 80%	1				onecker: Kuzr	ilakowski 12/	2004				Using ysa	t = 125 pcr	Using Ko	= 1 - SIN φ	_		Area = p	i " radius^2		1.310 sq π
_								ecieu i		. (1)	. (2)										ons ====> Head			1		
	ncorrected Blowcount	Material	Uncorrected Blowcount	Material	Uncorrected	Material		ean	Conversion Automatic	Sowers 1979 Phi Angle	DeMello 1971 Schmertmann	Effective Overburden	Average of (1) AND (2)	$\delta = \phi - 5$	Depth	Total Pressure	Pressure from Flow Net along	Effective Overburden	Effective Overburden	Ultimate Shear along	Side Resistance Along Pier	N <sub>qp</sub> End Bearing	End Bearing	End Bearing	Ultimate Side	
<u>                                     </u>	Siowcourit		BIOWCOUTL		BIOWCOUNT	l	\/:	alue	Trip Hammer	Fig 13	1975 Phi Angle	Pressure	(1) AND (2)	υ-ψ-5	Deptil	Along Pile	Riverside Pile	Pressure	Pressure	Length	Length	coefficient	Pressure	Resistance	and End Bearing	
	B-16		B-21		B-23			L	Use 1.2	Degrees	Fig 14 Degrees	(kgf / sq cm)	degrees	degrees		Psf	Psf	σv', Psf	σh', Psf	$\tau$ , psf	pounds	dimenionless	qb, psf	Qb, Pounds	Pounds	
pth												Note :	7						Driven Piers Use K =1							
)												1 Tsf =	27	22	0	0	0	0	0	0	0					1
												0.976 kgf /								0	0					
							<del>                                     </del>						27	22	3	375	496	0	0	0	0				1	
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					1								27	22	6	750	696	54	54	10.88	27 27	18.95	1021	1337	1365	-
															Ť	7.00	5.5		<u> </u>	1	•	10.00	1021	1001	1000	1
													27	22	9	1125	903	222	222	55.79	679 706	18.95	4214	5522	6228	
													21	22	9	1125	5.35	222	222		700	10.93	4214	3322	0228	1
			4	Silty Sand							0.5	0.700			40	4500	1 4440	050	1 050	116.07	1413	10.05			10007	
!							<del>                                     </del>	3	3.6	29	25	0.703	27	22	12	1500	1148 4.9	352	352		2119	18.95	6675	8747	10867	-
	4	Silty Sand	12	Silty Sand	3	Silty Clay														174.13	2120					
i			5	Silty Sand	1		-	5	6	29	29	0.937	28 29	23 24	15	1875	1386 4.5	489	489		4239	21.29	10403	13632	17871	
Ż	3	Silty Sand			4	Silty Clay			7			2.007	29.5	24.5						247.86	3017					1
9	8	Silty Sand	10	Silt	7		$\vdash$						30	25	18	2250	1625 4.1	625	625		7257	26.88	16797	22010	29267	4
0	U		10	Oiit	'	Sand	7	7.5	9	28.5	32	1.171	30.25	25.25						328.40	3998					
2	8	Silty Sand	18	Sand	10	Sand							30.3 30.5	25.3 25.5	21	2625	1851 3.8	774	774	386.79	11254 2354	27.84	21547	28235	39489	
+			10	Sanu	10	Sanu	<del> </del>						30.5	25.5	22.5	2812.5	1957	855	855	300.79	13609	28.49	24364	31926	45534	1
	2	Silty Sand	15	Sand	4	Sand		10	12	29.5	33	1.405	31.25	26.25	24	3000	3.7		•	•	13609		•	31926	45534	For Ultir
							<b>-</b>														Pounds Sum of Side			Pounds Sum of Side	Pounds Sum of Side	Displacemen
,	5	Sand	20	Sand	32	Sand									27	3375					Resistance			Resistance	Resistance	10% of pier di 1.8 inch
																					19' length pier			19' length pier	19' length pier	1.0 1110
			NOTES:													Notes :	Nqp from Fi	gure 4-4 of E	EM 1110-2-2	€with equati	on developed a	•	Be(0.1165*\phi')	to tongur pro-		
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A- e Side She	3, A-4, A-5 ar along pi	for equatio les include	dix 3, Borings ns, correlation pore water pre	s and essure	relationship reduction in	s. the effecti						Notes :	$q_b = \sigma v' * Nc$	ib			on developed a	a Nq = 0.8158	Be(0.1165*φ')	o ongui più		
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	$q_b = \sigma v' * Nc$	ib				a Nq = 0.8158	Зе(0.1165*ф¹)	o ougu pu		
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	$q_b = \sigma v' * No$ Side resistar	nce Along Pi	ier = Sum (τ <sub>c</sub>	Area <sub>dl</sub> ) , dl	on developed a	a Nq = 0.8158			058*tan 22\1	= 706
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	$q_b = \sigma v' * No$ Side resistar	nce Along Pi	ier = Sum (τ <sub>c</sub>	Area <sub>dl</sub> ) , dl	on developed a	a Nq = 0.8158			.058*tan 22)]	= 706
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	q <sub>b</sub> = σv' * Nc Side resistar Examp	nce Along Pi	ier = Sum (τ <sub>c</sub> eet; Side res	ai*Area <sub>di</sub> ) , dl	= incremental p 0+54)/2 * (6-3.5	a Nq = 0.8158  pile length  5)*4.058*tan 2	(2)]+[(54+2)]	22)/2 * (9-6)*4		= 706
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	q <sub>b</sub> = σv' * No	nce Along Pi	ier = Sum (τ <sub>c</sub> eet; Side res	ai*Area <sub>di</sub> ) , dl	e incremental p 0+54)/2 * (6-3.5 Net Head Abo Net Head = h- h = head abov	pile length  5)*4.058*tan 2  ove Landsid  Ah*(#Drops) ve landside g	e Existing Gr	22)/2 * (9-6)*4  ound Surface due to the rive	<b>9</b> :	= 706
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	q <sub>b</sub> = σv' * No	nce Along Pi	ier = Sum (τ <sub>c</sub> eet; Side res	*Area <sub>di</sub> ) , dl sistance =[ (C	= incremental p +54)/2 * (6-3.5 Net Head Abo Net Head = h-	pile length  ove Landsid  Ah*(#Drops) we landside ge pin for one equipotential december of equi	e Existing Gr round surface uipotential dro	22)/2 * (9-6)*4  ound Surface due to the rive p = h / N <sub>b</sub>	er level	
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	q <sub>b</sub> = σv' * No	nce Along Pi	ier = Sum (τ <sub>c</sub> eet; Side res	*Area <sub>di</sub> ) , dl sistance =[ (C	non developed a  = incremental p  0+54)/2 * (6-3.5)  Net Head Abo Net Head = h h = head abo Ah = head dro Ne = total equ rops : total incre along the p	ove Landsid  -\text{\tin\text{\texi{\text{\texi{\texi{\texi{\text{\texi{\texi{\texi{\texi{\texi{\texi\texi{\texi{\texi}\tiexi{\texi{\texi{\texi{\texi{\texi{\texi{\texi{\texi{\texi{\texi{	e Existing Gr round surface uipotential drops ipotential drop feet below the	22)/2 * (9-6)*4  ound Surface due to the rive p = h / N <sub>b</sub>	er level  n in the foundated and side ground	atioi
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> <li>Ti</li> </ol>	jes A-2, A- e Side She he depth is	3, A-4, A-5 ar along pi considere	for equation les included negative l	ns, correlation pore water pre pelow the land	is and essure Iside g	relationship reduction in ground surfa	s. the effection ce to deterr	nine the total	pressure h	nead.			Notes :	q <sub>b</sub> = σv' * No	nce Along Pi	ier = Sum (τ <sub>c</sub> eet; Side res	*Area <sub>di</sub> ) , dl sistance =[ (C	on developed a  = incremental p  0+54)/2 * (6-3.5)  Net Head Abo Net Head = h h = head abov Δh = head dro Ne = total equ rops : total incre along the p	pile length  ove Landsid -Δh*(#Drops) ve landside g pp for one equipotential droement of equipotential droement of equipotential droement of holy a from the to halp holy a from the to halp holy a from the second and above lan Total pressure.	e Existing Gr round surface uipotential drop feet below the f water on the flow net = 8 flos.75 dside ground re at 6 feet; F	ound Surface due to the rive p = h / N <sub>b</sub> to the location e top of the lar floodwall h= surface = 16.5	er level  In in the foundation in the foundation of the foundation	surface £

### **EXHIBIT A-7.22**



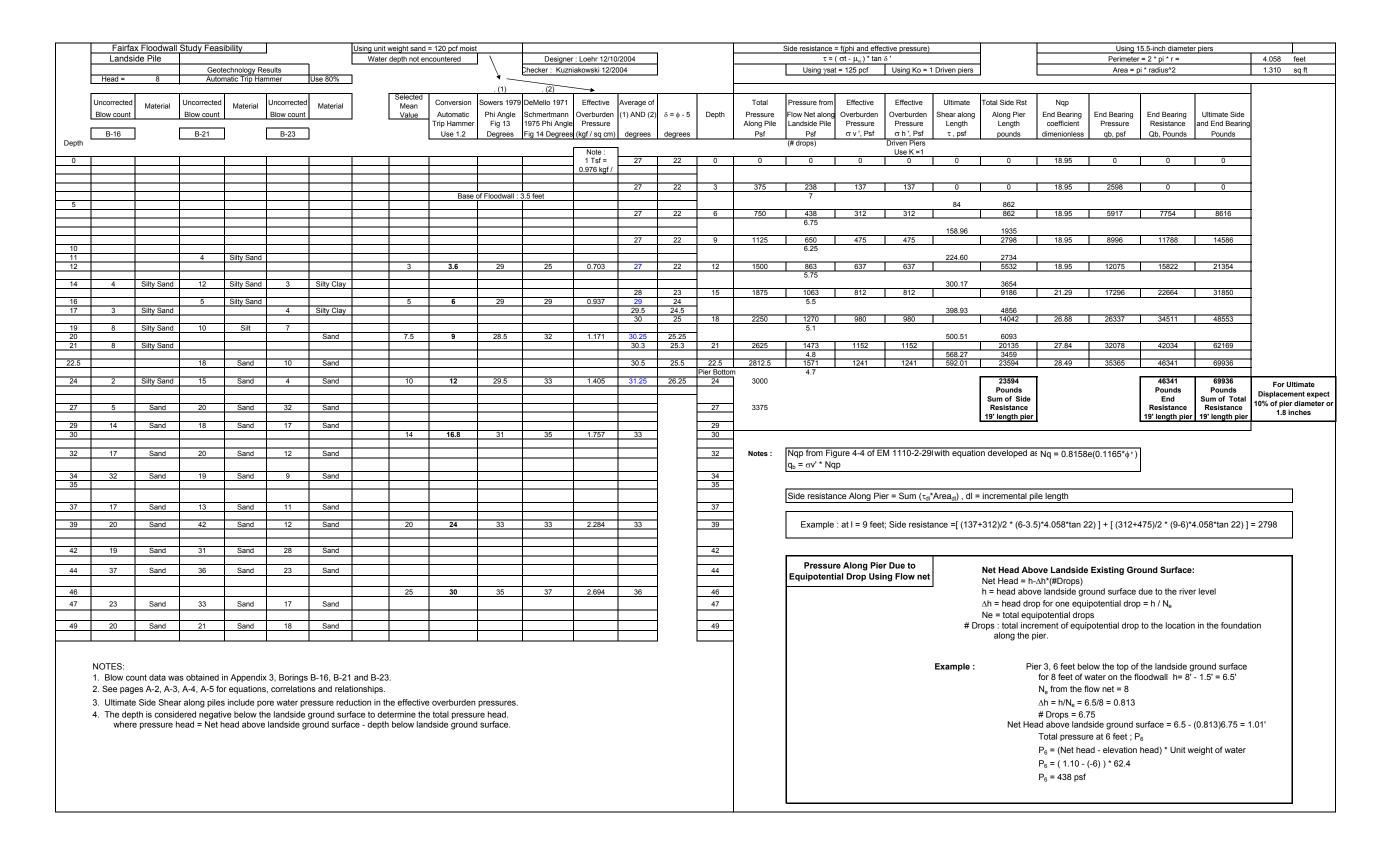
### **EXHIBIT A-7.22 (Continued)**

Mic		Study Feasib	ility			Using unit v	weight sand	= 120 pcf mois	st							Side resistance :	f(phi and effe	ctive pressure)				Using	15.5-inch diamete	r piers	
	dle Pile			.1	Ī		depth not en			Designe	r : Loehr 12/10	0/2004					σt - μ <sub>ω</sub> ) * tan						er = 2 * pi * r =		4.058 fee
		Geo	echnology Re	sults					•	Checker: Kuzn	niakowski 12/2	004				Using γsat	= 125 pcf	Using Ko	= 1 - sin φ '			Area =	pi * radius^2		1.310 sq
Water at T	OW Head =13'	Auto	matic Trip Har	nmer	Use 80%				. (1)	. (2)										_					1
Uncorrecte	d Material	Uncorrected	Material	Uncorrected	Material		Selected Mean	Conversion	Sowers 1979	DeMello 1971	Effective	Average of			Total	Pressure from	Effective	Effective	Ultimate	Side Resistance	$N_{qp}$				
Blowcount		Blowcount B-21	1 1	Blowcount B-23		ļ	Value	Automatic Trip Hammer Use 1.2	Fig 13	Schmertmann 1975 Phi Angle Fig 14 Degrees			$\delta = \phi - 5$ degrees	Depth	Pressure Along Pier Psf	Flow Net along Middle Pile Psf	Overburden Pressure σ v ', Psf	Overburden Pressure σ h ', Psf	Shear along Length τ, psf	Along Pier Length pounds	End Bearing coefficient dimenionless	End Bearing Pressure qb, psf	End Bearing Resistance Qb, Pounds	Ultimate Side and End Bearing Pounds	
			1		1		L				Note:	1	229.222				,	Driven Piers Use K =1	.,,,,	posee		4-, 1			
											1 Tsf = 0.976 kgf /	27	22	0	0	0	0	0	0	0					
												27	22	3	375	349	26	26	1	0					
									Top of Pile : 3.5	5'				3.5		6.2			45	456					
												27	22	6	750	554 6	196	196		456	18.95	3718	4872	5328	
												27	22	9	1125	768	357	357	112	1361 1817	18.95	6768	8868	10685	
		4	Silty Sand													5.7		•	175	2130					
							3	3.6	29	25	0.703	27	22	12	1500	991 5.3	509	509		3947	18.95	9647	12641	16587	
4	Silty Sand	12 5	Silty Sand Silty Sand	3	Silty Clay		5	6	29	29	0.937	28	23	15	1875	1205	670	670	244	2972 6919	21.29	14265	18692	25611	
3	Silty Sand		Siny Sand	4	Silty Clay		J	υ	29	28	0.937	29 29.5 30	24 24.5 25	18	2250	1419	831	831	334	4067 10986	26.88	22332	29263	40249	
8	Silty Sand	10	Silt	7	Sand		7.5	9	28.5	32	1.171	30.25	25.25	10	2200	4.7	031	001	428	5208	20.00	22332	23203	70243	1
8	Silty Sand				Garia		7.0		20.0			30.3	25.3	21	2625	1633 4.4	992	992	491	16194 2989	27.84	27605	36173	52367	
		18	Sand	10	Sand							30.5	25.5	22.5	2812.5	1736 4.3	1077	1077		19183 <b>19183</b>	28.49	30676	40196 <b>40196</b>	59379 <b>59379</b>	For Ulti
2	Silty Sand	15	Sand	4	Sand		10	12	29.5	33	1.405	31.25	26.25	24						Pounds Sum of Side			Pounds Sum of Side	Pounds Sum of Side	Displaceme
5	Sand	20	Sand																						
ı	<u> </u>	NOTES:		32	Sand									27	N-4	Nan from Eig	uro 4.4 of F	M 4440 2 20	(with equation	Resistance 19' length pier	N - 0 0450	) (0.440 <u>F</u> † L)	Resistance 19' length pier	Resistance 19' length pier	
	1	<ol> <li>See pag</li> <li>Ultimate</li> </ol>	es A-2, A-3 e Side Shea	ns obtained , A-4, A-5 t r along pile	I in Appendix for equations es include po	s, correlati ore water i	ions and re pressure r	elationships eduction in	the effective	overburden p		ad.		27	Notes :	$q_b = \sigma v' * Nq$ Side resistar	ce Along Pie	er = Sum (τ <sub>d</sub>	*Area <sub>dl</sub> ) , dl =		le length		19' length pier	19' length pier	1.8 inc
	ı	<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	es A-2, A-3 e Side Shea	ns obtained , A-4, A-5 t r along pile	I in Appendix for equations es include po	s, correlati ore water i	ions and re pressure r	elationships eduction in	the effective			ad.		27	Notes :	$q_b = \sigma v' * Nq$ Side resistar  Example	ce Along Pie : at I = 9 fee	er = Sum (τ <sub>d</sub> i et; Side resist	*Area <sub>d</sub> ) , di =	ength pier  and developed as  incremental pi  and 196)/2 * (6-3.5)  Net Head Abc  Net Head = h-	le length  )*4.058*tan 2:  ove Landside Δh*(#Drops) e landside gr pe landside gr ipotential droj ement of equi	2)]+[(196+ e Existing Gi ound surface ipotential dro	357)/2 * (9-6)*4  round Surface: e due to the rive p = h / N <sub>e</sub>	19' length pier	1.8 inc

### **EXHIBIT A-7.22 (Continued)**

			Study Feasib	oility			Using unit weig			ist				1			Side resistance							15.5-inch diamete	r piers	_	
H	Middle	e Pile	0	echnology Re	14-	, <u>l</u>	Water dept	th not en	countered	_		r : Loehr 12/10						( σt - μ <sub>ω</sub> ) * tan t = 125 pcf		-4 -:- 11	4			r = 2 * pi * r =		4.0	
١	Vater at TOV	W Head =18'		matic Trip Ha		Use 80%					Checker: Kuzr	ilakowski 12/2	004	1			Using γsa	t = 125 pcr		= 1 - sin φ '	<u> </u>		Area = [	oi * radius^2		1.3	0 sq 1
	ncorrected Blowcount	Material	Uncorrected Blowcount	Material	Uncorrected	Material	ı	Mean	Conversion	. (1) Sowers 1979 Phi Angle	. (2) DeMello 1971 Schmertmann	Effective Overburden	Average of (1) AND (2)	δ = φ - 5	Depth	Total Pressure	Pressure from Flow Net along	Effective Overburden	Effective Overburden	Head Condition Ultimate Shear along	Side Resistance Along Pier	= 18 feet  N <sub>qp</sub> End Bearing	End Bearing	End Bearing	Ultimate Side		
Ĺ	B-16		B-21	]	B-23	<u>'</u>		VAIIIE	Trip Hamme Use 1.2	Fig 13 Degrees	1975 Phi Angle Fig 14 Degrees	Pressure	degrees	,	.,.	Along Pier Psf	Middle Pile Psf	Pressure σ v ', Psf	Pressure σh', Psf	Length τ, psf	Length pounds	coefficient dimenionless	Pressure qb, psf	Resistance Qb, Pounds	and End Bearing Pounds	g	
	ı		1		T	1				1	T	Note : 1 Tsf =	27	22	I 0	0	1 0	0	Driven Piers Use K =1		0						
1												0.976 kgf /	21	22		0	0	0		0	0						
L													27	22	3.5	375	419 6.2	0	0	0	0						
ļ													27	22	6	750	632	118	118	23.88	60 60	18.95	2240	2935	2995	_	
F																7.00	6			77.89	948	10.00	2210	2000	2000		
ŀ													27	22	9	1125	858 5.7	267	267		1008	18.95	5068	6640	7648	1	
ŀ			4	Silty Sand				3	3.6	29	25	0.703	27	22	12	1500	1096	404	404	135.57	1650 2658	18.95	7651	10026	12684	_	
	4	Silty Sand	12	Silty Sand	3	Silty Clay											5.3			198.12	2412						
Ī			5	Silty Sand				5	6	29	29	0.937	28 29	23 24	15	1875	1322 5	553	553		5070	21.29	11773	15427	20497		
£	3	Silty Sand			4	Silty Clay							29.5 30	24.5 25	18	2250	1548	702	702	279.38	3401 8471	26.88	18873	24730	33201	1	
‡	8	Silty Sand	10	Silt	7	Sand		7.5	9	28.5	32	1.171	30.25	25.25		0005	4.7	051	051	364.65	4439	07.04	00007	04050	10000		
t	8	Silty Sand	18	Sand	10	Sand							30.3 30.5 30.5		21 22.5	2625 2812.5	1774 4.4 1880	932	851 932	423.45	12910 2577 15488	27.84	23697 26564	31052 34809	43962 50297		
ŧ	2	Silty Sand	15	Sand	4	Sand		10	12	29.5	33	1.405	31.25	26.25	24	3000	4.3	932	932		15488	20.49	20504	34809	50297		or Ulti
															27	3375					Pounds Sum of Side Resistance			Pounds Sum of Side Resistance	Pounds Sum of Side Resistance	10% o	aceme
	5	Sand	20	Sand	32	Sand								j	2.	1					19' length pier			19' length pier	19' length pier	· <u> </u>	1.8 inc
	5	Sand	NOTES: 1. Blow co 2. See pag	ount data wates A-2, A-3	as obtained	in Appendix	3, Borings I	s and r	elationship	S.	e overburden	pressures.		j		Notes :	Nqp from Fig $q_b = \sigma v' * Nc$		M 1110-2-29	(with equation		Nq = 0.8158	e(0.1165*φ')	19' length pier	19' length pier	•	1.8 inc
	5	Sand	NOTES: 1. Blow co 2. See pag 3. Ultimate	ount data wates A-2, A-3	as obtainec 3, A-4, A-5 t ar along pile	in Appendix or equations es include po	, correlation ore water pre	s and r	elationship reduction ir	s. the effective	e overburden		ad.			1	$q_b = \sigma v' * Nc$	p			19' length pier	·	e(0.1165*φ')	19' length pier	19' length pier	·	1.8 inc
	5	Sand	NOTES: 1. Blow co 2. See pag 3. Ultimate	ount data wates A-2, A-3	as obtainec 3, A-4, A-5 t ar along pile	in Appendix or equations es include po	, correlation ore water pre	s and r	elationship reduction ir	s. the effective			ad.	1	-	1	$q_b = \sigma v' * No$ Side resistar	p nce Along Pie	er = Sum (τ <sub>d</sub>	·Area <sub>dl</sub> ) , dl =	19' length pier	le length					1.8 inc
	5	Sand	NOTES: 1. Blow co 2. See pag 3. Ultimate	ount data wates A-2, A-3	as obtainec 3, A-4, A-5 t ar along pile	in Appendix or equations es include po	, correlation ore water pre	s and r	elationship reduction ir	s. the effective			ad.		-	1	g <sub>b</sub> = σν' * No	p nce Along Pie e : at I = 9 fer	er = Sum $(\tau_{di})$ et; Side resis	·Area <sub>dl</sub> ) , dl =	on developed as incremental pi	le length *4.058*tan 22	)]+[(118+2	67)/2 * (9-6)*4	.058*tan 22) ] :		1.8 incl
	5	Sand	NOTES: 1. Blow co 2. See pag 3. Ultimate	ount data wates A-2, A-3	as obtainec 3, A-4, A-5 t ar along pile	in Appendix or equations es include po	, correlation ore water pre	s and r	elationship reduction ir	s. the effective			ad.		-	1	g <sub>b</sub> = σν' * No	p nce Along Pie e : at I = 9 fer	er = Sum (τ <sub>d</sub> i et; Side resis	Area <sub>dl</sub> ) , dl =	19' length pier	ile length  *4.058*tan 22   ove Landside Δh*(#Drops) e landside grape landside grape landside grape landside grape landside grape landside grapent of equi	Existing Ground surface potential drops	67)/2 * (9-6)*4.  ound Surface due to the rive $p = h / N_e$	.058*tan 22) ] =	= 1008	1.8 inc
	5	Sand	NOTES: 1. Blow co 2. See pag 3. Ultimate	ount data wates A-2, A-3	as obtainec 3, A-4, A-5 t ar along pile	in Appendix or equations es include po	, correlation ore water pre	s and r	elationship reduction ir	s. the effective			ad.			1	g <sub>b</sub> = σν' * No	p nce Along Pie e : at I = 9 fer	er = Sum $(\tau_{di})$ et; Side resis	Area <sub>dl</sub> ) , dl =	n developed as incremental pi  118)/2 * (6-3.5)  Net Head Abc Net Head = h- h = head abov Δh = head equ rops: total incre along the p	ve Landside Δh*(#Drops) e landside gr p for one equi ipotential drop ement of equi ier.	Existing Ground surface potential drop so contential drop ow the top of eet of water o ow net = 8	67)/2 * (9-6)*4.  ound Surface due to the rive $p = h / N_e$	.058*tan 22) ] : : r level n in the founda	= 1008	1.8 inc

### **EXHIBIT A-7.23**



### **EXHIBIT A-7.23 (Continued)**

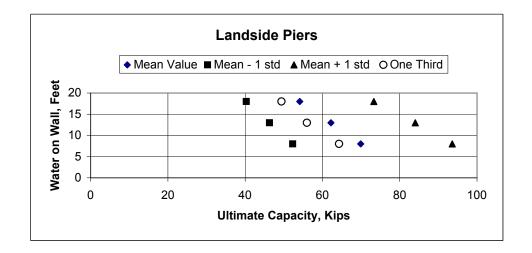
-			Study Feasib	oility	j				= 120 pcf moist	1	<u> </u>	on I a - b - 10/11	2/2004	1			Side resistance			<u> </u>	-			5.5-inch diameter	r piers	4.050 (
-	Landside F	Pile	0	4bl D-			Water	depth not en	countered			er : Loehr 12/10 niakowski 12/2		_	F			( σt - μ <sub>ω</sub> ) * tan		-4 -:- 11	4			= 2 * pi * r =		4.058 fee
Water	at TOW H	lead =13'		technology Re matic Trip Har		Use 80%	1				pnecker: Kuz	makowski 12/2	004	1			Using $\gamma$ sa	t = 125 pcf	Using Ko	= 1 - sin φ'	ا ا		Area = p	i * radius^2		1.310 sc
							1			. (1)	. (2)	_	1	1				1							I	
Uncorr	rected	Material	Uncorrected	Material	Uncorrected	Material		Selected Mean	Conversion	Sowers 1979	DeMello 1971	Effective	Average of			Total	Pressure from	Effective	Effective	Ultimate	Side Resistance	$N_{qp}$				
Blowd		atoria.	Blowcount	matorial	Blowcount	Matorial		Value	Automatic	Phi Angle	Schmertmann		(1) AND (2)	$\delta = \phi - 5$	Depth	Pressure	Flow Net along	Overburden	Overburden	Shear along	Along Pier	End Bearing	End Bearing	End Bearing	Ultimate Side	
В.	16	Г	D 24		D 22	i			Trip Hammer	Fig 13	1975 Phi Angl	le Pressure es (kgf / sq cm)	dograna	dograpa		Along Pile	Landside Pile Psf	Pressure σ v ', Psf	Pressure σh', Psf	Length τ, psf	Length	coefficient	Pressure	Resistance Qb, Pounds	and End Bearing Pounds	
D-	16	L	B-21	_	B-23			Į	Use 1.2	Degrees	rig 14 Degree	es (kgi / sq ciii)	degrees	degrees	l l	Psf	PSI	0 7 , FSI	Driven Piers	ι, μει	pounds	dimenionless	qb, psf	QD, Pourius	Pourius	
	-			_	1		1	1 1			ı	Note : 1 Tsf =	27	22	0	0	1 0		Use K =1	Ι 0					П	
												0.976 kgf /	21	22	U	U	0	0	1 0	0	0				l	
													27	22	2	375	277	98	98	1	0				1	
									1	Top of Pile : 3.	5'		27	22	3 → 3.5	3/5	7	90	90	1					I.	ł
													27	22	6	750	487	263	263	73	741 741	18.95	4993	6543	7284	<u> </u>
													21	22	0	750	6.75	203	203	1		10.95	4993	0343	7204	1
													27	22	9	1125	719	406	406	135	1647 2388	18.95	7703	10093	12482	<u> </u>
													21	22	9	1125	6.25	400	400	1		10.95	1103	10093	12402	1
			4	Silty Sand				3	3.6	29	25	0.703	27	22	12	1500	951	549	549	193	2351 4739	18.95	10412	13643	18382	ļ
								J	3.0	23	23	0.703	21	22	12	1300	5.75	343	343	1		10.33	10412	13043	10302	<u> </u>
4	Si	Silty Sand	12	Silty Sand	3	Silty Clay					<u></u>		28	23	15	1875	1160	715	715	262	3187 7926	21.29	15220	19943	27869	}
			5	Silty Sand				5	6	29	29	0.937	29	24		.575	5.5	. 10				220	.0220	.0040	2.500	İ
3	Sil	Silty Sand		1	4	Silty Clay							29.5 30	24.5 25	18	2250	1383	867	867	352	4286 12212	26.88	23297	30527	42739	<u> </u>
8	Sil Sil	Silty Sand	10	Silt	7	0- 1		7.		00.5		4 171			-		5.1									1
8	B Si	Silty Sand		+		Sand		7.5	9	28.5	32	1.171	30.25 30.3	25.25 25.3	21	2625	1597	1028	1028	445	5413 17625	27.84	28604	37482	55107	ł
		Í	40	0	40	0							20.5		00.5	2812.5	4.8	4440	4440	508	3093		31698	41536	62254	Į
			18	Sand	10	Sand						-	30.5	25.5	22.5	2812.5	1700 4.7	1112	1112	1	20718 <b>20718</b>	28.49	31098	41536 41536	62254	For Ulti
2	? Sii	Silty Sand	15	Sand	4	Sand		10	12	29.5	33	1.405	31.25	26.25	24						Pounds Sum of Side			Pounds	Pounds Sum of Side	Displaceme
	-																				Resistance			Sum of Side Resistance	Resistance	10% of pier d
5	j .	Sand	20	Sand	32	Sand									27						19' length pier			19' length pier	19' length pier	1.8 Inc
			2. See pag 3. Ultimat	ges A-2, A-3 e Side Shea	, A-4, A-5 fo or along pile	or equations s include po	s, correlat ore water	ions and re pressure re	eduction in th	ne effective o							$q_b = \sigma v' * Nc$	•								
									urface to det urface - dept								Side resista	nce Along Pi	er = Sum (τ <sub>d</sub>	*Area <sub>dl</sub> ) , dl =	incremental pil	e length				
									negative belo								Example	e : at I = 9 fee	et; Side resis	tance =[ (98+	-263)/2 * (6-3.5)	)*4.058*tan 2	2)]+[(263+4	06)/2 * (9-6)*4	.058*tan 22) ] =	= 2388
																		re Along Pie ial Drop Usi		i	Net Head Abo Net Head = h- h = head abov  Δh = head drop	∆h*(#Drops) e landside gr o for one equ	ound surface of	due to the rive		
																				Example :	Ne = total equi # Drop : total ir along the pi	ncrement of e	equipotential d	·	tion in the foun	
																				·		$N_e$ from the f $\Delta h = h/N_e = 0$ # Drops = 6.	low net = 8 11.5/8 = 1.437 75		= 11.5' (1.4375)6.75 =	1.80'
																						•	re at 6 feet ; P	6	Unit weight of v	vater

### **EXHIBIT A-7.23 (Continued)**

-		rfax Floodwal	Study Feasib	oility		ļ	Using unit weight s						10004				Side resistance							5.5-inch diamete	er piers	1	
<u> </u>	Landsid	de Pile	0	technology Re	oulto	, <u>L</u>	Water depth n	ot encou	untered	-		: Loehr 12/10			-			( σt - μ <sub>ω</sub> ) * tan		= 1 air 11	4	-		= 2 * pi * r =		4.05	
W	ater at TOV	N Head =18'		tecnnology Re matic Trip Har		Use 80%				E	hecker : Kuzni	akowski 12/20	004				Using $\gamma$ sa	t = 125 pcf	Using Ko	= 1 - sin \( \phi \)	_		Area = p	oi * radius^2		1.31	0 sq fi
_	1			,	1		Carler	en i		. (1)	. (2)										ons ====> Head						
	corrected	Material	Uncorrected	Material	Uncorrected	Material	Mea	III I		Sowers 1979			Average of	$\delta = \phi - 5$	Dareth	Total	Pressure from	Effective	Effective	Ultimate	Side Resistance	N <sub>qp</sub>	Ford December	Ford Donaire	Lillian - An Oid -		
В	owcount		Blowcount	l .	Blowcount		Valı		Automatic rip Hammer	Phi Angle S Fig 13	Schmertmann 1975 Phi Angle	Overburden Pressure	(1) AND (2)	ο = φ - 5	Depth	Pressure Along Pile	Flow Net along Landside Pile	Overburden Pressure	Overburden Pressure	Shear along Length	Along Pier Length	End Bearing coefficient	End Bearing Pressure	End Bearing Resistance	Ultimate Side and End Bearing		
	B-16		B-21	1	B-23				Use 1.2		ig 14 Degrees		degrees	degrees		Psf	Psf	σv', Psf	σh', Psf	τ, psf	pounds	dimenionless	qb, psf	Qb, Pounds	Pounds	,	
				_							ľ	NI-4-	1						Driven Piers							1	
T												Note : 1 Tsf =	27	22	0	0	0	0	Use K =1 0	0	0					1	
												0.976 kgf /								0	0					7	
_													27	22	3	375	316	59	59	0	0					+	
															3.5		7					•	•	•		7	
													27	22	6	750	535	215	215	55.32	138 138	18.95	4069	5332	5471	+	
																	6.75	•	1		•		•	•		7	
													27	22	9	1125	787	338	338	111.69	1360 1498	18.95	6409	8398	9896	4	
															Ů	1120	6.25	000		1	•	10.00	0.00	0000	0000	7	
			4	Silty Sand			3	_	3.6	29	25	0.703	27	22	12	1500	1038	462	462	161.57	1967 3465	18.95	8749	11464	14929	4	
							Ű		0.0	20	20	0.700			12	1000	5.75	402	702	ı	•	10.00	0140	11404	14020	7	
_	4	Silty Sand	12	Silty Sand	3	Silty Clay							28	23	15	1875	1258	617	617	223.44	2720 6185	21.29	13144	17223	23408	4	
			5	Silty Sand			5		6	29	29	0.937	29	24	10	1073	5.5	017	017	1	•	21.29	13144	17225	23400	7	
L	3	Silty Sand		ļ	4	Silty Clay		$ \Gamma$					29.5 30	24.5 25	18	2250	1496	754	754	305.16	3715 9900	26.88	20257	26543	36443	4	
	8	Silty Sand	10	Silt	7										10	2230	5.1	734	7.54		•	20.00	20257	20343	30443	7	
	8	Silty Sand				Sand	7.5	i	9	28.5	32	1.171	30.25 30.3	25.25 25.3	21	2625	1722	903	903	388.82	4733 14633	27.84	25130	32929	47563	4	
	Ů	Only Ourid	18	Sand	10	Sand							30.5	25.5			4.8			447.90	2726					İ	
-	2	Silty Sand	15	Sand	4	Sand	10		12	29.5	33	1.405	30.5 31.25	25.5 26.25	22.5 24	2812.5 3000	1829 4.7	984	984		17360 17360	28.49	28031	36731 <b>36731</b>	54090 <b>54090</b>	+-	
		Only Garia	15	Janu	7	Janu	10		12	29.5	33	1.403	31.23	20.23	27	3000	4.7				Pounds			Pounds	Pounds	Dienle	or Ultir
	5	Sand	20	Sand	32	Sand															Sum of Side				Sum of Side		
	3	Sanu	20	Sanu	32	Saliu			+							2275								Sum of Side			
			NOTES:				I								27	3375 Notes :			M 1110-2-29	Owith equation	Resistance 19' length pier	i≲ Nq = 0.8158	·	Resistance 19' length pier	Resistance 19' length pier	10% 01	pier d
			1. Blow co 2. See pag	jes A-2, A-3	, A-4, A-5 fo	or equations	3, Borings B-1	nd relati	itionships.						27		Nqp from Fig $q_b = \sigma v' * Nq$		M 1110-2-29	Wwith equation	Resistance 19' length pier	s Nq = 0.8158	·	Resistance 19' length pier	Resistance	10% 01	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea	, A-4, A-5 for ar along pile	or equations s include po		nd relati ire redu	itionships. luction in the						2/		$q_b = \sigma v' * Nq$	db.			Resistance 19' length pier		·	Resistance 19' length pier	Resistance	10% 01	pier di
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			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<u>.</u>		27		$q_b = \sigma V' * Nq$ Side resistar	nce Along Pie	er = Sum (τ <sub>d</sub>	*Area <sub>dl</sub> ) , dI =	Resistance 19' length pier	ile length	Se(0.1165*φ')	Resistance 19' length pier	Resistance 19' length pier	10% or	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>.</b>		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie	er = Sum (τ <sub>d</sub> et; Side resis	*Area <sub>dl</sub> ) , dI =	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5	ile length	3e(0.1165*φ¹) 2)]+[(215+3	Resistance 19' length pier	Resistance 19' length pier	10% or	pler di 1.8 inch
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>.</b>		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5	ile length 5)*4.058*tan 2:	3e(0.1165*φ¹) 2)]+[(215+3	Resistance 19' length pier	Resistance 19' length pier	10% or	pler di 1.8 inch
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>9</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5	ile length 5)*4.058*tan 2:  ove Landside -∆h*(#Drops)	3e(0.1165*\(\phi\)') 2)]+[(215+3	Resistance 19' length pier	Resistance 19' length pler	10% or	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>3</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi  +215)/2 * (6-3.5	ille length 5)*4.058*tan 2:  ove Landside -\( \text{\Landside} \) \( \text{\Landside} \)	3e(0.1165*\(\phi\)') 2)]+[(215+3) <b>e Existing Gro</b> round surface (	Resistance 19' length pier	Resistance 19' length pler	10% or	i pier di 1.8 incl
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	Э.		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head = h h = head abo Δh = head dro Ne = total equ	ile length  ove Landside -Δh*(#Drops) ve landside gr p for one equ uipotential drop	Be(0.1165*\psi^*)  2)]+[(215+3)  Be Existing Ground surface or ipotential dropps	Resistance 19' length pier  138)/2 * (9-6)*4  Dund Surface: due to the river 0 = h / N <sub>e</sub>	Resistance 19' length pier	] = 1498	pier di
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	Э.		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5)  Net Head Abo Net Head = h h = head abo \[ \Delta h = head dro \]	ille length  5)*4.058*tan 2:  ove Landside -Δh*(#Drops) ve landside gr op for one equ uipotential drop increment of e	Be(0.1165*\psi^*)  2)]+[(215+3)  Be Existing Ground surface or ipotential dropps	Resistance 19' length pier  138)/2 * (9-6)*4  Dund Surface: due to the river 0 = h / N <sub>e</sub>	Resistance 19' length pier	] = 1498	i pier di 1.8 incl
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	Э.		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head = h h = head abo Δh = head dro Ne = total equ # Drop: total i along the p	ove Landside  -\text{\tinx}\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\text{\tex{\tex	Be(0.1165*\(\phi\)')  2)]+[(215+3)  Be Existing Ground surface on ipotential drop psequipotential d	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the rive 10 = h / N <sub>e</sub> Irop to the loca	Resistance 19' length pier	] = 1498	pler di 1.8 inch
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>.</b>		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>di</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi  +215)/2 * (6-3.5  Net Head Abo Net Head = h- h = head abo Oh = head abo Ne = total equ # Drop: total i along the p	ille length  ive Landside  Δh*(#Drops)  ve landside gr  purpose from one equ  purpose f	Be(0.1165*\(\phi^*\))  2)]+[(215+3)  Existing Ground surface or cound surf	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the rive 10 = h / N <sub>e</sub> Irop to the loca	Resistance 19 length pier  1.058*tan 22) ]  : pr level ation in the four	] = 1498	i pier di 1.8 incl
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>.</b>		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi  +215)/2 * (6-3.5  Net Head Abo Net Head = h- h = head abo Δh = head dro Ne = total equi # Drop: total i along the pi for 13	ille length  ive Landside  Δh*(#Drops)  ve landside gr  purpose from one equ  purpose f	Be(0.1165*\psi^*)  2)]+[(215+3)  Be Existing Ground surface or injoint and for possible possible possible for the foodward of the foodward food the foodward food the foodward food food food food food food food fo	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> Irop to the loca	Resistance 19 length pier  1.058*tan 22) ]  : pr level ation in the four	] = 1498	pler di 1.8 inch
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>9</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head = h- h = head abo \[ \Delta \text{h} = head dro \] Ne = total equilibria along the pi for 13	ille length  ille length  ive Landside  Δh*(#Drops)  ve landside gr  pp for one equ  iipotential drop  increment of e  oier.  er 3, 6 feet be  feet of water of  N <sub>e</sub> from the f	Be(0.1165*\psi^*)  2)]+[(215+3)  Be Existing Ground surface or injoint and for possible possible possible for the foodward of the foodward food the foodward food the foodward food food food food food food food fo	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> Irop to the loca	Resistance 19 length pier  1.058*tan 22) ]  : pr level ation in the four	] = 1498	pler di
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>9</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5)  Net Head Abo Net Head = h- h = head abo ∆h = head dro Ne = total equ # Drop: total i along the p	ove Landside  \[ \Delta \text{An'}(\pm\) Tops) \\ ve landside grop for one equipotential dropincement of epier.  \[ er 3, 6 feet be feet of water of the months of t	Be(0.1165*\(\phi\)')  2)]+[(215+3)  Existing Ground surface of the componential drop ps are appropriately appropriately approximately approxim	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the river 0 = h / N <sub>e</sub> Irop to the loca the landside g Ill h= 18' - 1.5'	Resistance 19' length pier  1.058*tan 22) ]  : er level ation in the four	] = 1498	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>3</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head abo Ah = head abo Ah = head dro Ne = total equ # Drop: total i along the p  Pictor 13:  Net Head	ove Landside  Ah'(#Drops) ve landside grop for one equipotential dropincrement of epier.  er 3, 6 feet be feet of water of Ne from the form the following the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of water of the feet of	Be(0.1165*\(\phi^*\))  2)]+[(215+3)  Existing Ground surface or inpotential drop ps equipotential drop of on the floodwarflow net = 8 16.5/8 = 2.06 75 dside ground s	Resistance 19' length pier  138)/2 * (9-6)*4  Dound Surface: due to the river 0 = h / N <sub>e</sub> Irop to the loca the landside g 11 h= 18' - 1.5'	Resistance 19 length pier  1.058*tan 22) ]  : pr level ation in the four	] = 1498	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	Э.		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head abo Ah = head abo Ah = head dro Ne = total equ # Drop: total i along the p  Pictor 13:  Net Head	ove Landside	Be(0.1165*\( \phi^* \))  Be Existing Ground surface or cound y or country o	Resistance 19' length pier  338)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> irop to the loca the landside g all h= 18' - 1.5'  surface = 16.5 - 16' 6'	Resistance 19' length pier  3.058*tan 22) ]  : er level ation in the four	] = 1498 in	pier dia
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>3</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head abo Ah = head abo Ah = head dro Ne = total equ # Drop : total i along the p Pictor 13:	ove Landside	Be(0.1165*\( \phi^* \))  Be Existing Ground surface or cound y surface or country su	Resistance 19' length pier  338)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> irop to the loca the landside g all h= 18' - 1.5'  surface = 16.5 - 16' 6'	Resistance 19' length pier  1.058*tan 22) ]  : er level ation in the four	] = 1498 in	pier di 1.8 incl
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<u>.</u>		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head abo Ah = head abo Ah = head dro Ne = total equ # Drop : total i along the p Pictor 13:	ove Landside $\Delta h^*$ (#Drops) ve landside grops for one equipipotential drop increment of epier.  er 3, 6 feet be feet of water of $\Delta h = h/N_e = 1$ # Drops = 6. ad above land Total pressur $P_6 = (N_e = 1.25 + 1.00)$ $P_6 = (2.58 - 1.00)$	Be(0.1165*\phi*)  2)]+[(215+3)  Be Existing Ground surface of the control of the control of the floodwarflow net = 8 16.5/8 = 2.06 75 15 15 16 16 16 16 16 16 16 16 16 16 16 16 16	Resistance 19' length pier  338)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> irop to the loca the landside g all h= 18' - 1.5'  surface = 16.5 - 16' 6'	Resistance 19' length pier  3.058*tan 22) ]  : er level ation in the four	] = 1498 in	pier di 1.8 incl
			<ol> <li>Blow co</li> <li>See pag</li> <li>Ultimate</li> </ol>	jes A-2, A-3 e Side Shea oth is consid	, A-4, A-5 fo or along pile dered negat	or equations s include po tive below th	s, correlations and ore water pressume landside grou	nd relati ire redu ind surf	tionships. luction in the face to dete	ermine the to	otal pressure	head.	<b>3</b> .		27		q <sub>b</sub> = σv' * Nq Side resistar  Example	nce Along Pie  a: at I = 9 fee	er = Sum ( $\tau_{dl}$ et; Side resis	*Area <sub>dl</sub> ) , dl = tance =[ (59-	Resistance 19' length pier  on developed a  = incremental pi +215)/2 * (6-3.5  Net Head Abo Net Head abo Ah = head abo Ah = head dro Ne = total equ # Drop : total i along the p Pictor 13:	ove Landside	Be(0.1165*\phi*)  2)]+[(215+3)  Be Existing Ground surface of the control of the control of the floodwarflow net = 8 16.5/8 = 2.06 75 15 15 16 16 16 16 16 16 16 16 16 16 16 16 16	Resistance 19' length pier  338)/2 * (9-6)*4  Dound Surface: due to the rivel 0 = h / N <sub>e</sub> irop to the loca the landside g all h= 18' - 1.5'  surface = 16.5 - 16' 6'	Resistance 19' length pier  3.058*tan 22) ]  : er level ation in the four	] = 1498 in	pier d

### **EXHIBIT A-7.24**

Phi angle	15.5 dia Pier Location	Height on Wall Feet	Ultimate Capacity, Kips
Mean Value	Landside	8 13 18	69.9 62.2 54.1
Mean - 1 std	Landside	8 13 18	52.3 46.3 40.3
Mean + 1 std	Landside	8 13 18	93.6 84 73.3
One Third	Landside	8 13 18	64.3 56 49.4



			,
Phi angle	15.5 dia Pier Location	Height on Wall	Ultimate
		Feet	Capacity, Kips
		8	68.5
Mean Value	Mid	13	59.4
		18	50.3
		8	50.7
Mean - 1 std	Mid	13	43.8
		18	36.9
		8	91
Mean + 1 std	Mid	13	79.8
		18	67.4
		8	62.2
One Third	Mid	13	52.7
		18	44

Phi angle	15.5 dia Pier Location	Height on Wall	Ultimate
		Feet	Capacity, Kips
		8	66.6
Mean Value	Riverside	13	55.9
		18	45.5
		8	49.1
Mean - 1 std	Riverside	13	41.1
		18	33.1
		8	88.2
Mean + 1 std	Riverside	13	75.1
		18	61
		8	60.1
One Third	Riverside	13	49.2
		18	39.6
			·

